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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS,

ABSTRACTS OF PAPERS,

AND

REPORTS OF THE PROCEEDINGS

OF

THE SOCIETY,

FROM NOVEMBER 1861, *TO JUNE* 1862.

VOL. XXII.

BEING THE ANNUAL HALF-VOLUME OF THE MEMOIRS AND PROCEEDINGS
OF THE ROYAL ASTRONOMICAL SOCIETY.

LONDON:

PRINTED BY

STRANGEWAYS & WALDEN, CASTLE STREET, LEICESTER SQUARE.

1862.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. XXII. *November* 8, 1861. No. 1.

Dr. Lee, President, in the Chair.

Col. T. Schaffner, Kentucky, U.S.A.,

was balloted for and duly elected a Fellow of the Society.

Extract of a Letter from Professor Hansen to the Astronomer Royal, dated Gotha, 1861, *Oct.* 18.

My principal labours advance progressively, and I work at them with pleasure. Events in the last summer have indeed occasioned some delay, and my other various avocations also often create cessations, but nevertheless I proceed. The working out of the new terms depending upon the planets, which I mentioned in my last letter, has occasioned a considerable addition to the labour of the calculation of the secular variation of the Moon's mean longitude, which I have not yet quite completed. I must in fact execute in regard to these terms as great a labour as in the calculation of the lunar perturbations themselves. I must carry on the approximations until the values at last substituted come out again. These terms are far greater than I suspected at first, and the circumstance that here the coefficients of the terms which have very small divisors become remarkably large particularly increases this labour. In the lunar perturbations themselves the analogous terms have only small coefficients. I am, I may say, perfectly

convinced that the value of the secular variation which I have before calculated from theory and assumed in the Lunar Tables must again come out, although I have considerably changed the method of calculation.

In the calculation of the secular variation of the mean longitude, I have set out with the proposition that the element which I have always denoted by Ξ has no influence over it. This proposition I have already proved, even to the cube of the disturbing forces, in my third memoir upon the perturbation of the small planets, and the proof holds also for the Moon. Further, the numerical equations of condition have shown me that this proposition is true even for the higher powers of the disturbing forces, at least to a considerable extent.

I have calculated anew the principal part of the perturbations of the longitude, of the radius vector, and of the latitude, and obtained such an agreement with the coefficients used by me in the Lunar Tables, and derived from the previous theoretical calculations that the differences in the individual coefficients amount only to a few hundredths of a second of arc. A new calculation of the secular variation of the motion of the perigee is also finished, and the deviation of the coefficient thus found from that of the Lunar Tables scarcely amounts to $0''\cdot4$. Now this coefficient, multiplied only by $2\,e$, enters into the longitude; and as $2\,e$ is nearly $=\frac{1}{9}$, this difference is of no greater significance than $0''\cdot04$ in the coefficient of the secular variation of the mean longitude.

As I have brought such accuracy into my theoretical determinations of the various parts of the Lunar Theory, it of course follows that I do not need to deem the cry which some have raised concerning empiricism finding place therein deserving of the least notice.

In order, however, as much as possible to comply with every reasonable desire concerning the early publication of my theoretical determination of the coefficients of the Lunar Theory, I have occupied myself, for some short time past, with putting together and sending to the press my calculation of the principal perturbations, which, as stated above, has been executed afresh. As soon as possible will follow, also, the publication of the calculation of the smaller coefficients. You will ask perhaps why I then do not publish the first calculations, which were finished long ago, before the completion of the Lunar Tables? and I answer, that I executed the last approximations in that calculation by substitution of the differences with the preceding approximation, and that therefore, by the publication of these calculations, a complication would arise which could only be made intelligible with great difficulty.

In the publication the result must proceed from *one* fountain; and it was necessary, therefore, that a new approximation should be calculated, with the full values of the coefficients. Only in this manner can I make myself clear, and place every

one in a position to be able to examine with ease the individual parts of my calculation.

With regard to the two small errors in the Lunar Tables which you communicate to me, they have arisen in this manner:—Page 86, Arg. 37 and (a) have, according to my present re-calculation, been calculated by my former computer, who has made so many errors, with an incorrect coefficient of $(c-18)^3$. The influence of this error, however, is so insignificant that it can, even in the year −800, produce an effect, at the most, of $1''\cdot8$ upon the Moon's longitude, and, as a matter of course, still less in subsequent centuries. I consider, therefore, its correction to be superfluous. Page 77, Arg. 10, Year −500, 56·619 was written by mistake instead of 56·691.

Note by the Astronomer Royal.

The small errors to which Professor Hansen alludes in the last paragraph were pointed out by Dr. Hincks to the Astronomer Royal, in a letter dated 1861, Sept. 16. Dr. Hincks remarks, "The whole columns 37 and (a), p. 86, are miscalculated, the error in the former being proportional to the cube of the number of centuries before 1800. $\overset{37}{9\cdot1823} + \overset{(a)}{275}$ ought to be 9·1350 + 330; and so in other instances down to 1600, when the error disappears. I happened to notice a minor error in p. 77, −500, Arg. 10, where 56·619 is printed for 56·691. This, however, produces no sensible error."

On a Result deduced by M. D'Abbadie from Observations of the Total Solar Eclipse of 1860, *July* 18. By the Astronomer Royal.

In the *Compte Rendu* of the French Academy for the meeting of 1860, November 12 (tome li.), M. Antoine D'Abbadie has given an account of his observations of the eclipse of July 18, and in particular of his measures of the height of a certain red prominence A, to which my present remarks are confined. The telescope employed had an aperture of $72^{\text{mm}}\cdot5$ (2·9 inches nearly), a focal length of 800^{mm} (32 inches nearly), and was used with a magnifying power 47. The micrometer consisted of a glass plate in the field of view, bearing a net of equal divisions, which divided the whole field into squares of $51''$ each side.

Omitting all observations except those which I have specified, M. D'Abbadie's record is as follows:—

No. de l'Observation.	Temps Moyen.	Phénomène Noté.	Angle reduit en hauteur.
	h m s		′
3	2 47 45	Hauteur de A, 1·3 division (probablement 2·3).	1·9
5	2 48 26	Hauteur de A, 1·3 division, dont une en diagonale.	1·4
7	2 49 27	Hauteur de A, 0·7 division.	0·6

upon which he founds the following inferences:—

"En calculant le mouvement relatif des deux astres par les Tables de MM. Hansen et Le Verrier, et en comparant les différences à celles qu'on deduit de mes observations relatées ci-dessus, on obtient les résultats suivans,—

Numeros.	Diminution observée dans la hauteur de la prot. A.	Mouvement correspondant calculé de cette partie du disque.	Mouvement maximum calculé dans la direction même du mouvement relatif des deux astres.
	″	″	″
De 3 à 5	30	15·0	18·3
De 5 à 7	52	22·4	27·2

"Ici, la decroissance observée est plus de deux fois celle qui serait produite par le simple mouvement relatif des deux astres."

We owe it entirely to the candour of M. D'Abbadie and to the completeness of his published statement, that we are in any way enabled to criticise his conclusions. I trust, therefore, that, in expressing my inability to agree with M. D'Abbadie as to the method of treating his observations and as to the results to be drawn from them, I may be understood as offering to him my thanks and those of other persons interested in this discussion, for the clear and full account of his original observations, from which we are all enabled to frame our own deductions.

The conclusion of M. D'Abbadie regarding the discordance between the observed decrease of the prominence and the computed change in relative positions of the Sun and Moon, rests *entirely* upon his arbitrary correction of the first observation; where his recorded measure was 1·3, which measure he has changed with the simple remark "probablement 2·3", and has used so changed in the subsequent computations. There is nothing to lead to the supposition that any circumstance attending the observation itself called for a change. It has been made, as far as we can judge, simply because the progress in the measured height of the protuberance between 3 and 5 is inconsistent with that between 5 and 7: it has, in fact, the wrong sign.

But if we are permitted to make such changes, where shall we stop? Why not alter the measure 5 instead of 3, which would have led to a discordance in the opposite direction? I conceive that it is much safer to use the observations as they

stand, to extract from them the best result which mathematics enable us to draw, to form the numerical values of the residual errors, and to judge whether these can properly be attributed to error of observation.

Adopting, then, for observation 3 the *original* value 1·3, and considering the diagonal measure in observation 5 as 1·4, we have the following measures of the height of the prominence:—

No.	Mean Time.	Height of A in divisions.	Height of A in seconds.
	h m s		
3	2 47 45	1·3	66
5	2 48 26	1·7	87
7	2 49 27	0·7	36

Let x be the height of the prominence at $2^h\ 47^m\ 0^s$, y the decrease in its height for 1^m. Then we have

$$x - y \times 0{\cdot}75 = 66$$
$$x - y \times 1{\cdot}43 = 87$$
$$x - y \times 2{\cdot}45 = 36$$

Treating these by the method of Probable Errors, we obtain the equations

$$3x \quad - y \times 4{\cdot}63 = 189{\cdot}0$$
$$x \times 4{\cdot}63 - y \times 8{\cdot}60 = 262{\cdot}1$$

by solution of which, $x = 93{\cdot}8$, $y = 20$.

The rate of change for 1^m, therefore, inferred from the observations, is $20''$, agreeing sensibly with $22''$ given by the computed relative motion of the Sun and Moon.

If we substitute for the formula $93{\cdot}8 - 20 \times t$ (where t is expressed by fractions of a minute) in each of the observations, we obtain

No.	Computed Height of Prominence.	Observed Height of Prominence.	Excess of Observed Height.
	$''$	$''$	$''$
3	78·8	66	−12·8
5	65·2	87	+21·8
7	44·8	36	− 8·8

From my own experience in observations of eclipses, I conceive that these "excesses," though very large, are not beyond possibility. The second measure (in which it seems to have been necessary to resort to a comparison with the diagonal of the square, I can scarcely imagine why) was evidently made under unfavourable circumstances; and the power of the telescope was low.

I think that M. D'Abbadie's inference is not sustained by his observations.

Royal Observatory, Greenwich,
1861, *October* 22.

Total Solar Eclipse, 1861, *Dec.* 31.
By J. R. Hind, Esq.

The following Table, exhibiting the path of the Moon's shadow over the African continent, in the eclipse of 1861, Dec. 31, has been derived from accurate calculations founded upon the Tables of Le Verrier and Hansen, assuming the diameters of Sun and Moon as there adopted:—

Greenwich Mean Time.	N. Limit. Long.	N. Limit. Lat.	Central Line. Long.	Central Line. Lat.	S. Limit. Long.	S. Limit. Lat.	Duration of Totality on Central Line.
h m	° ′	° ′	° ′	° ′	° ′	° ′	m s
2 33	18 13 W.	14 30 N.	18 8 W.	14 11 N.	18 2 W.	13 52 N.	1 43
2 38	16 24	15 36	16 19	15 18	16 14	15 0	1 38
2 43	14 28	16 49	14 23	16 32	14 18	16 14	1 33
2 48	12 21	18 10	12 17	17 53	12 13	17 35	1 27
2 53	10 1	19 40	9 58	19 23	9 54	19 6	1 20
2 58	7 23	21 21	7 21	21 5	7 18	20 49	1 13
3 3	4 18	23 19	4 17	23 3	4 16	22 47	1 5
3 8	0 32 W.	25 40	0 33 W.	25 25	0 33 W.	25 10	0 56
3 10	1 17 E.	26 45	1 15 E.	26 31	1 14 E.	26 16	0 52
3 12	3 22	27 59	3 19	27 45	3 17	27 32	0 48
3 14	5 50	29 25	5 47	29 12	5 44	28 58	0 43
3 15	7 18	30 15	7 14	30 1	7 10	29 48	0 40
3 16	9 0	31 10	8 54	30 57	8 48	30 44	0 37
3 17	11 2	32 16	10 53	32 2	10 46	31 49	0 34
3 18	13 42 E.	33 39 N.	13 29 E.	33 24 N.	13 17 E.	33 9 N.	0 31

Nautical Almanac Office,
1861, *Nov.* 2.

Observations of the Solar Spots. By Rev. F. Howlett.

Mr. Howlett presented to the Society a further series of drawings of solar spots. The following is extracted from the letter, dated St. Augustine's Parsonage, Hurst Green, Sussex, Nov. 5th, 1861, which accompanied the drawings:—

"The present series, continued from Nov. 15th, 1860, and brought down to Oct. 31st of the present year, consists of about seventy-three drawings of the whole solar disk, as magnified about 30 diameters, besides upwards of 200 separate spots, grouped or single, as amplified from 120 to 150 diameters.

"I may be permitted to remark that the wonderful commotions exhibited on the solar surface during the years 1859 and 1860 have scarcely, I think, been equalled at any period during the year which is now drawing to a close. These commotions,

indeed, would appear to be now calming down—consistently, so far, with the much-discussed eleven-year cycle of maximum and minimum of spots.

"At no time, however, this year have I ever observed the Sun to be entirely devoid of spots: the two barest days might, I think, be stated as the 1st Feb. and 9th Oct. last, as may be inferred from the condition of the disks when respectively depicted on the 2d Feb. and 10th Oct. (as shown in sheets Nos. 37 and 58); whilst the spots of the latter part of March, and of the last half also of April and May, were very grand (as see sheets Nos. 41, 43, 44, and 47, especially the last).

"The preponderance of spots occurred, as usual, in the Sun's northern hemisphere; indeed, during the ninety-nine days upon which I made records of these appearances, I found, as nearly as I could judge, that a northern preponderance obtained on 47 days, and a southern one on 28; the spots on the remaining 24 days of recorded observation being nearly equally distributed in both hemispheres.

"The longest series that I have been able to depict of the changes undergone by any one individual spot is that exhibited in nine separate drawings of the spot ν (see sheets 43 and 44), between the period of its first being observed by me on the 16th April and the condition it was in on April 26th, including the alteration suffered even between the hour of 7·30 A.M. and 3·0 P.M. on April 17th.

"A peculiar eddy seems to have strongly characterised the spot numbered 2, in group χ (sheet 54), as observed at 6·20 A.M. on July 29th, but which had nearly ceased, judging from appearances, at 2·15 P.M. on the same day.

"I may also, perhaps, be allowed to call attention to the manner in which I have endeavoured to represent, approximately, the inclination to the horizon, at different hours of the day, of the line of junction of two spots on the Sun's surface, as recorded also on July 29th. The subject is interesting, as far as the matter of spherical geometry is concerned; and not less so, perhaps, as regards the best time for drawing the solar disk—in the way, at least, with which I am obliged at present to content myself, as alluded to in my last communication to the Society.

"The absence of penumbra on the north-east side of so large a spot as β (see Aug. 19th, sheet 56) is, I should imagine, very unusual.

"I would only desire to remark, further, the impression which is increasingly felt by me of the extreme *shallowness*, by comparison, of the photospheric stratum in which is sunk the penumbra of spots generally, and even of the penumbral stratum itself; inasmuch as the nuclei commonly remain visible to almost the very edge of the disk, the penumbral border of a spot very seldom presenting much appearance of foreshortening, either; so far, at least, as I could perceive, though armed with

a Dawes's solar eye-piece, by Dollond, with a magnifying power of 200 diameters, and with an ordinary astronomical eye-piece, of about 300 diameters, appertaining to one of the Society's Sheepshanks Equatoreals, by Simms.

"This assumed shallowness of the *photosphere*, indeed, seems *proved* by Mr. Nasmyth's most interesting discovery of the thin layer of luminous lenticular bodies, of which that observer asserts the solar surface to consist.

"On the other hand, the *nuclear stratum*, or perhaps *strata*, appears to be of prodigious thickness, as may be inferred from the evidently vast depths into which the nuclear orifices descend, and as the varying intensity of blackness in different parts of the same nucleus seems also to bespeak. See series of large spot ζ throughout sheet 41, and series also of the grand spot ν in sheets 47 and 48, where the idea seems forced upon one, of chasms descending through cloudy strata, dozens or perhaps rather scores of thousands of miles in perpendicular depth."

Description of a portion of the Lunar Surface seen at Dr. Lee's Observatory at Hartwell, on the morning of July 31, 1861. By W. R. Birt, Esq.

The Roman numerals refer to the accompanying sketch which is taken from Beer and Mädler's map of the Lunar Surface.

I. *Cichus.* — A deep crater on the south-west extremity of a very rugged portion of high land, forming part of the south-east boundary of the *Mare Nubium.*

Mr. Webb thus speaks of *Cichus :*—

"*Cichus,* 189, on index map, a crater opened in table land, lies 9000 feet beneath the plateau, 4000 feet below the plain; its ring is perforated by a smaller crater, an object of

great interest. In 1833 I perceived that it was twice as large as it had been represented three several times by Schröter. On becoming possessed of the great map, I found it there also enlarged. Schröter, though a clumsy, was a faithful draughtsman; his views have the appearance of being each independently drawn, and they are under different angles of illumination, which often vary the size of small craters, so that here is *fair evidence of volcanic action* since 1792; the silence of Beer and Mädler being characteristic, goes for little or nothing."

Webb gives two figures; one, copied from Schröter's design, 1792, Jan. 4; the other, taken from Beer and Mädler's map. I am not in possession of Schröter's.

II. *Cichus* A, marked C in Beer and Mädler's map, a small but deep crater on the south-east margin of the ridge of *Cichus*. This small crater should be most carefully watched and measured; only a portion of the margin was seen this morning, as a projecting tongue of light into the dark shadow within the larger crater.

III. A crater north of *Cichus*, given in the small German map, but singularly omitted in the large map. There is a very obscure marking in the neighbourhood of the fault next to be described, *where I saw the crater exceedingly well defined;* but it has on the map not the remotest resemblance to a crater: it is situated between two mountain masses marked β and γ. This is also an object that requires close attention.

IV. A fault north-east of III., forming the south-west portion of a somewhat narrow triangular mass of very high land, about 5000 feet; see quotation from Webb. It is also very rugged. This mass of high and rugged land is well shown on the large German map.

V. A small crater west of *Cichus*, marked B on the large German map.

VI. A crater near the boundary of the *Mare Nubium*, forming with III. and V. an isosceles triangle, III. and V. being the base. The position of this crater, as I saw it, does not accord with its position on the large map. I apprehend it to be really more southerly than marked by Beer and Mädler. Westward of this are *four* small craters, which I failed to see. *Query*, were they too much advanced on the terminator?

VII. A portion of high land, on the south-east extremity of which *e* (VI.) is situated. The small German map gives a ridge hereabout; it does not, however, terminate as I saw it. It is very much better delineated on the large map.

VIII. A crater marked A on the large map, on the east edge of *Hesiod*, which is now on the terminator. Its outline is perceptible, but the floor is in perfect darkness.

IX. The east edge of a crater now in shadow, which does not appear to be given in the German map. The east ridge is, however, well given in the large map; it is connected with the

boundary of a large space south of *Hesiod*, presenting (on the map) the appearance of a large disrupted crater (unnamed).

X. A small crater marked D on the large map: it is north-east of *e* (VI.)

XI. A small crater nearly, but not quite, in a line with VI. and X., also given in the German maps, but delineated in the larger map as being much more diminutive in comparison with the craters in its neighbourhood than I saw it. It is *undesignated*, probably as having been an inconspicuous object at the date of Beer and Mädler's labours.

XII. A small serpentine mountain chain between X. and XI. given in the German maps.

XIII. A rille or canal brought out most exquisitely by the Hartwell telescope, but no traces of its consisting of minute craters, although examined with a power of 416. The utmost I could detect was a very narrow gutter-like formed canal running north-west and south-east, or thereabout, from *Hesiod* to near the steep and rugged south-east boundary of the *Mare Nubium*, the north-east interior slope being in shadow, the south-west in sunshine. I estimated it to be somewhat about a mile wide. It is well delineated on the German map, and is marked δ.

XIV. A short mountain-range running nearly at right angles from one extremity of the triangular mass of high land, described at IV., and at right angles generally to the steep and rugged boundary of the *Mare Nubium*, to the two craters *Mercator* and *Campanus*. It is given very distinctly on the larger map.

XV. A small conical mountain (?) very apparent north-east of, and closely abutting on, the rille or canal XIII. (δ). This is not given on the German map, and no traces whatever can be seen on the larger map. It would be well to watch very closely the neighbourhood of this mountain, especially as the surface of the *Mare* is exceedingly smooth, north-east of the canal.

XVI. Western edge of the high land forming the south-west part of the mass on which *Cichus* is situated; shown on the large map.

From VI. in the direction of X. towards XII., and as far as XIV., the surface is studded with small mountains (hillocks in comparison with the larger mountain masses), clearly separating the smoother spaces within IX. and XVI. from the general surface of the *Mare*. This appearance of being thus studded is shown on the larger map. The space between IX. and XVI. being separated from the general surface has greatly the appearance of having been a portion of a large ancient crater, probably broken up by the formation of this portion of the boundary of the *Mare Nubium*.

The above described observations were made with Dr. Lee's great Equatoreal, object-glass by Tully, on July 30, 1861, between 13 and 15 hours G.M.T. Power employed 240.

The Lunar Crater Plato.

Mr. Birt communicated a series of observations of this well-known crater, embracing a period of eighteen months, viz., from January 1860 to July 1861, which he had arranged according to the Moon's age, so that they not only served as a record of the past, but can also be used as an Ephemeris, indicating to the observer the appearances likely to be seen, and thus form the basis of an accurate course of observations on the physical aspects of *Plato*, and by means of which changes, if any, may be detected. There are several sketches of the spot and also portions of it. The observations are preceded by an index, referring to the Moon's age at which each observation was made, and followed by a summary of objects suitable for further telescopic observation in or near *Plato*. The whole are bound in a volume, which is deposited in the Library for reference and circulation.

On an Instrument for comparing Colours, proposed to be designated a Homochromascope. By W. R. Birt, Esq.

In the course of my observations on the physical characteristics of the Moon's surface, I found it necessary to devise some means for comparing with known standards of colour the tints of various portions, especially the dark-floored craters, the extensive grey plains, and the more luminous districts in immediate proximity with the rayed craters. After various trials, I found the instrument of which a somewhat rough model is now exhibited* the best adapted for the purpose. It is intended to consist of a moveable cradle, possessing a rack-work motion receiving one of a series of glass plates; on each plate a certain number of disks are painted with transparent colours, each colour being experimentally determined by means of an instrument similar in its construction and action to the colour top. The numerical value of every tint can thus be precisely ascertained. The cradle, with its plate of glass, is moved within a box having a circular aperture, top and bottom, exactly equal to the coloured disk; so that, while the strong light of a lamp enclosed in a lantern is thrown on a highly reflective surface attached to the box, the disk is viewed by the light thus reflected and transmitted through it. In this way, while the eye carefully contemplates the tints of the lunar disk, it is also able to compare them with the tints

* The model was exhibited at the Meeting.—Ed.

on the glass plates, which, being properly arranged and numbered, the tints observed can be easily registered. The instrument, mounted on a tripod, may be conveniently placed near the telescope for observation.

It is highly important that, in all observations with an instrument of this kind, the flame of the lamp should always be of the same intensity. This may be secured by a simple arrangement in the construction of the lamp and the burner. The construction of the instrument ensures permanency of tint in every other respect.

Results of the Meridional Observations of Small Planets; Occultations of Stars by the Moon; and Phenomena of Jupiter's Satellites: observed at the Royal Observatory, Greenwich, during the months of June to October, 1861.

(*Communicated by the Astronomer Royal.*)

Iris (7).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, June 5	9 55 0·1	14 52 12·22	109 52 52·70
12	9 23 6·8	14 47 49·58	......

Irene (14).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Oct. 4	13 54 11·2	2 49 5·82	85 6 19·01
11	13 21 52·4	2 44 17·64	85 32 41·28
22	12 29 31·3	2 35 10·04	86 13 6·78
26	12 10 9·7	2 31 31·46	86 26 30·64

Phocæa (25).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Sept. 20	12 18 24·9	0 17 51·36	65 43 23·93
26	11 50 33·2	0 13 35·10	67 34 32·82
27	11 45 55·0	0 12 52·76	67 54 11·71
30	11 32 2·8	0 10 47·92	68 54 43·27
Oct. 4	11 13 41·3	0 8 9·61	70 18 14·85
9	10 51 5·8	0 5 13·14	72 5 4·88
11	10 42 11·6	0 4 10·62	72 48 3·05
19	10 7 30·7	0 0 56·37	75 36 38·05

Calliope (22).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Sept. 12	11 12 25·4	22 40 9·31	120 47 44·84
Oct. 4	9 31 33·1	22 25 44·66	120 21 49·34

Bellona (28).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Sept. 23	13 1 35·4	1 12 59·30	93 17 12·29
Oct. 11	11 37 21·9	0 59 29·91	95 27 52·16
14	11 23 13·2	0 57 8·58	95 46 52·83
22	10 45 49·0	0 51 10·66	96 30 55·27

Urania (30).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, June 27	11 52 14·4	18 16 30·02	115 22 39·46
July 4	11 17 8·8	18 8 54·64	115 19 3·65
11	10 42 33·5	18 1 49·51	115 12 54·83

Ariadne (43).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Sept. 10	13 56 51·2	1 17 9·01	75 32 46·37
Oct. 11	11 26 51·5	0 48 57·79	78 24 5·09
14	11 12 9·8	0 46 3·36	78 46 39·54
19	10 47 58·9	0 41 31·32	79 24 28·19
22	10 33 41·0	0 39 0·68	79 46 29·44

Nysa (44).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, June 15	11 19 30·1	16 56 21·70	107 57 28·05

Europa (52).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Oct. 4	12 7 18·3	1 1 55·42	93 56 7·94
22	10 43 46·1	0 49 7·39	95 22 52·42

Pseudo-Daphne (56).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Sept. 3	9 33 5·8	20 25 4·37	97 36 41·29
5	9 25 11·9	20 25 2·31	97 51 51·54
12	8 58 33·7	20 25 55·59	98 43 11·06

Niobe (71).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Aug. 19	12 19 43·9	22 13 1·62	89 55 19·32

All the observations of N.P.D. have been corrected for refraction and parallax, excepting that of *Niobe*, which has been corrected for refraction only.

Occultations of Stars by the Moon.

Day of Obs.	Phenomenon.	Moon's Limb.	Mean Solar Time.	Observer.
			h m s	
1861, June 25	18 Aquarii, disapp.	Bright	11 39 59·1	D.
Sept. 14	ϖ Capricorni, disapp.	Dark	8 3 44·0	E.
14	ϱ Capricorni, disapp.	Dark	9 17 44·1	E.
14	ϱ Capricorni, reapp. (*a*)	Bright	10 29 55·3	E.
Oct. 20	ξ Arietis, disapp.	Bright	7 16 34·0	N.
22	103 Tauri, disapp.	Bright	12 35 58·4	M. D.

(*a*), Perhaps doubtful to one or two seconds.

The initials D., E., M. D., and N. are those of Mr. Dunkin, Mr. Ellis, Mr. Dolman, and Mr. Newcomb.

Phenomena of Jupiter's Satellites.

Day of Observation.	Satellite.	Phenomenon.	Mean Solar Time.	Observer.
1861.			h m s	
June 12	I.	Occ. disapp, first cont.	9 57 15·0	C.
12	I.	,, total disapp.	9 59 44·5	C.
13	I.	Egress, bisected. (*a*)	9 40 51·5	J. C.

(*a*) The planet very tremulous and diffused.

The initials C. and J. C. are those of Mr. Criswick and Mr. Carpenter.

Occultation observed at Highbury. By T. W. Burr, Esq.

1861, September 14th. The star *ϱ Capricorni* was occulted instantaneously by the dark limb of the Moon at $20^h\ 52^m\ 38^s{\cdot}9$ local sidereal time. Telescope 4 ft. 4 in. focus, $3\frac{3}{8}$ in. aperture, power 173. Longitude 24^s W.

Nov. 7th, 1861.

Places of the Comet II., 1861, from Sextant-Observations of the Distances of the Comet from Fixed Stars, made by Commander A. L. Mansell, R.N., commanding H.M.S. Firefly, and reduced under the superintendence of the Rev. George Fisher, Principal of the Greenwich Hospital Schools, by the Officers of that Establishment.

(*Communicated by the Astronomer Royal.*)

A short time since, the Admiralty placed in my hands a sheet of observations of the distances of the Comet II., 1861, from fixed stars, made by Commander A. L. Mansell, accompanied with the particulars which were absolutely necessary for their reduction, but with nothing tending to facilitate the reduction. At my request, the Rev. George Fisher most kindly took charge of the observations, and under his care they were reduced by the Officers of the Greenwich Hospital Schools.

The observations were made on board H.M.S. Firefly, her anchorage being within a quarter of a mile of the observatory-station used in the survey of Sidon, the position of which is—latitude $33^\circ\ 34''\ 26'$ N., longitude $35^\circ\ 21'\ 39''$ E. The latitude is determined from a mean of four meridian altitudes of α and β *Libræ* south of the zenith, and ten observations of *Polaris*, using the *Nautical Almanac* method. The longitude is determined from three good meridian distances from Beirut, using eight chronometers; Beirut being fixed by a mean of seven meridian distances, using seven chronometers, run between it and Malta. The longitude of Malta is deduced from that of the Observatory at Palermo. [It will be remarked, in the subsequent computations, that a small error of latitude produces no error in the deduced place of the comet, except in so far as it alters the computed altitude of the star and comet, and therefore slightly alters the refraction and the correction of distance; and a small error of longitude produces no effect, except in the correction of distance for refraction, and in the computation of the comet's place from the Ephemeris.] Mean time was deter-

mined by equal altitudes of the Sun on the 2d and 8th of July. $\frac{210}{3063}$ is a good pocket-chronometer, by French: it has however always been compared with the standard chronometer (Dent, 1793), which watch shows a good mean of the nine chronometers.

The elements given are—the Greenwich mean time of each observation, and the observed distance, index-error, and corrected apparent distance.

It does not appear necessary to give all the numbers of the observations, or the troublesome reductions, but it may be proper to describe the method pursued:—

1. The Comet's R.A., N.P.D., and log. distance were interpolated from the Ephemeris published by M. Le Verrier in the *Bulletin*. The hour-angle being found, the true altitude was computed; and by calculation of refraction and parallax, the apparent altitude was found.

2. The Star's R.A. and N.P.D. being taken from the *Nautical Almanac*, its true altitude was computed, and by calculation of refraction the apparent altitude was found.

3. From the two apparent altitudes and the measured distance, with the corrections of altitudes, the true distance was found by the usual method of clearing Lunars.

4. The distances of the Comet from the two stars were measured at different times. But on each of the evenings the distance of the Comet from at least one star was measured twice; and the change of distance for a known interval being thus found, it was always possible to reduce to the same moment the measures of distance from two stars.

5. With the R.A. and N.P.D. of the two stars, the distance between them was soon found, and the angle made by that distance with the meridian of one star. The three sides of the triangle formed by the Comet and two stars being known, the angle at the star last mentioned was computed. Applying this angle to the angle just mentioned, the angle made by the Comet's distance with the star's meridian was found. The necessary elements for computing its diff. R.A. and its N.P.D. were thus completely obtained.

The following are the results for the Comet's place:—

Day.	G.M.T.	Comet's R.A.	Comet's N.P.D.	Stars from which the Comet's Distance was measured.
1861.	h m s	h m s	° ′ ″	
July 1	6 17 30	7 17 43·75	35 49 19·3	Polaris, Spica.
	6 21 13	7 17 54·55	35 45 24·7	Spica, α Coronæ.
	6 40 53	7 18 37·46	35 43 37·5	Polaris, Spica.
	6 42 25	7 18 43·80	35 39 39·4	Spica, α Coronæ.
2	6 6 17	8 17 30·55	28 40 28·4	Polaris, Spica.
	6 9 28	8 17 48·02	28 36 30·0	Spica, α Coronæ.
	8 52 33	8 25 7·69	28 3 56·1	Polaris, Spica.

Day.	G.M.T.	Comet's R.A.	Comet's N.P.D.	Stars from which the Comet's Distance was measured.
1861.	h m s	h m s	° ′ ″	
July 2	8 58 24	8 25 27·25	28 1 0·3	Spica, α Coronæ.
4	6 11 2	10 38 18·35	23 6 1·4	Spica, α Coronæ.
	6 15 19	10 37 49·00	23 9 9·7	Polaris, Spica.
5	7 44 33	11 39 5·43	23 32 3·8	Polaris, Arcturus.
	7 46 52	11 39 14·10	23 31 33·6	Arcturus, α Lyræ.
6	8 28 11	12 21 59·50	24 51 2·6	Polaris, Arcturus (not favourable).
	8 30 37	12 22 57·85	24 47 42·5	Arcturus, α Lyræ.
8	6 23 16	13 14 31·54	27 42 22·0	Polaris, Arcturus (unfavourable).
	6 29 40	13 14 43·99	27 42 38·1	Arcturus, α Lyræ.
9	6 32 26	13 31 43·01	29 9 5·8	Polaris, Arcturus (unfavourable).
	6 36 10	13 32 12·24	29 8 35·3	Arcturus, α Lyræ.
10	6 24 29	13 43 48·79	30 26 10·4	Polaris, Arcturus (unfavourable).
	6 28 28	13 45 33·27	30 24 20·3	Arcturus, α Lyræ.

November 4, 1861.

Places of Comet II. 1861. By N. M. R. Edmondson, Esq., Assistant, Armagh Observatory.

(*Communicated by Dr. Robinson.*)

G.M.T.	R.A.	Par. in R.A.	N.P.D.	Par. in N.P.D.
	h m s	s	° ′ ″	″
July 1·4516	7 28 6·38	$+ \varpi \times$ 0·0406	34 17 24·94	$- \varpi \times$ 0·8468
2·5157	8 36 7 *		27 20 *	
5·4739	11 46 52·63	0·0965	23 44 3·01	0·3383
6·4883	12 28 16·27	0·0908	25 18 19·22	0·3200
7·4954	12 57 27·90	0·0864	26 32 1·64	0·3088
9·4864	13 34 59·05	0·0755	29 25 58·07	0·2480
10·4464	13 47 43·69	0·0628	30 39 20·46	0·1304
14·4583	14 18 48·34	0·0570	34 36 52·47	0·1968
16·4787	14 27 38 *		36 5 *	
18·4496	14 34 43·12	0·0515	37 13 3·49	0·2143
21·4722	14 42 27 *		38 34 *	
23·4581	14 46 32·56	0·0520	39 26 16·47	0·2798

* Approximate.

	Comparison Stars.	Assumed Places.	Obs.
(1)	Federenko's Lalande 1166	Lalande	1
(2)	R.A. = $8^h 36^m 1^s$*, N.P.D. = 27° 14′		2
(3)	Lalande 22785	ditto	4
(4)	Groombridge 1888	R.A. from Radcliffe; N.P.D. from Armagh	3
	,, 1926	Armagh Catalogue	4
	P. xiii. 110	ditto	4
	,, 233	ditto	5
	Groombridge 2102	ditto	5
	R.A. = $14^h 34^m 42^s$*, N.P.D. = 36° 0′*		3
	P. xiv. 164	ditto	5
	R.A. = $14^h 7^m 48^s$*, N.P.D. = 38° 33′*		1
	Radcliffe Catalogue	Radcliffe Catalogue	3

* Approximate.

Nov. 9th, 1861.

The Hydrographer of the Admiralty has communicated Observations taken by Mr. J. F. Krabbe, Master H. M. S. Meander, at Ascension Island, 1861, July 4, 8, and 29, of a Comet seen there, and which is, in fact, Comet II., 1861. The observations are sextant observations of the distances from three stars.

Sir Thomas Maclear, Director of the Royal Observatory at the Cape of Good Hope, has communicated to the Society a series of Right Asceusions and North Polar Distances of Comet III., 1860, deduced from observations made with the $8\frac{1}{2}$-feet Equatoreal at the Observatory. The observations extend from 9 July to 18 Oct. 1860. The paper probably will appear *in extenso* in the *Memoirs* of the Society.

Observations made at the Dudley Observatory, Albany, New York. By G. N. Hough, Esq., Assistant.

(*Communicated by Prof. O. M. Mitchell, Director of the Observatory.*)

Observations of Comet II. 1861, *made with the Equatoreal.*

Date.	M.T. of Obs.	App. R.A.	App. Decl.
	h m s	h m s	° ′ ″
Aug. 3	10 30 17·56	15 2 47·41	+47 29 14·87
10	10 54 35·16	15 10 38·48	
14	11 0 47·20	15 14 55·95	+45 34 20·17
15	9 57 45·91	15 15 57·44	

Aug. 3	Comp. ✱, 4961 Rumker		3 Comp.	
10	,,	15266, 15309 Arg.	5 ,,	
14	,,	15272, 15290 Arg.	7 ,,	Comet faint; moonlight
15	,,	15290 Arg.	6 ,,	Comet faint; moonlight

Occultation of 101 *Piscium by the Moon.*

1861, Aug. 24 $11^h\ 26^m\ 31^s{\cdot}0$ Mean Time.

Disappearance instantaneous. Telescope (13 in.) Equatoreal.

Observation of Minor Planets made with the Olcott Meridian Circle at the Dudley Observatory.

Calliope (22).

1861.	M.S.T. of Obs. h m s	App. R.A. h m s	App. Decl. ° ′ ″
Aug. 30	12 13 55·49	22 51 23·25	
31	12 9 6·87	22 50 30·40	−30 23 24·79
Sept. 4	11 49 51·57	22 46 58·15	−30 28 33·21
9	11 25 49·98	22 42 35·38	−30 42 27·33
12	11 11 29·18	22 40 2·28	−30 48 58·88
13	11 6 45·26	22 39 13·74	−30 49 17·53

Themis (24).

1861.	M.S.T. of Obs. h m s	App. R.A. h m s	App. Decl. ° ′ ″
Aug. 31	12 23 10·43	23 4 36·27	−6 55 42·58
Sept. 1	12 18 31·97	23 3 53·60	−7 0 2·65
4	12 4 35·23	23 1 44·23	−7 13 8·93
9	11 41 18·94	22 58 6·89	−7 34 52·85
12	11 27 22·48	22 55 57·79	−7 47 41·83
13	11 22 45·01	22 55 16·11	−7 51 47·38
24	10 32 11·52	22 47 56·40	−8 34 23·38

On a New Observing Clock. By Prof. C. Piazzi Smyth Astronomer Royal for Scotland. (Abstract.)

The desideratum of obtaining a clock with an easily audible seconds' tick has been realised by Mr. R. L. Jones' patent method, to which Prof. Smyth was introduced by letters from Sir T. Maclear and Mr. Hartnup; and Mr. Jones himself procured a second-hand cast-iron barrel clock without striking parts, and having introduced into it his magnetic pendulum brought to the Edinburgh Observatory in April last, and

erected it in front of the transit instrument and in electric connexion with the old transit clock, removed for this purpose out of its former position and into the central hall of the Observatory.

The new observing clock goes as accurately as, because simultaneously with, the old transit or regulating clock, but with a vigour or mechanical power more than three hundred times greater, its driving weight being 180 lbs., descending 10 feet in one day, instead of 5 lbs., descending 3 feet in 7 days. The seconds' tick, though loud, was at first a peculiarly slumberous, heavy, and mournful sound, but this was remedied, as suggested by Mr. F. Ritchie, clockmaker in Edinburgh, by obtaining the seconds beat, not in the usual and almost invariable method by the escapement, but, by introducing for the purpose a tilt hammer striking on an anvil, the escapement being rendered noiseless, so as not to interfere with the note of the hammer. The most appropriate quality of sound was found to be produced by a steel hammer striking on an anvil of hard olive wood, hollowed out below, so as to be under one quarter of an inch thick. It would have been an advantage, as regards loudness, to have the hammer and anvil outside the case of the clock in the free open air of the room: this was not actually done, but the casing was taken in the form of a wooden tubing to them, and almost as loud a beat was obtained. The cost of the production of the electricity is trifling, and, as regards the first cost of the apparatus, Mr. Ritchie, having been recently applied to on the part of a Canadian Observatory, has estimated the cost of a big observing clock, with its hammer, anvil, and galvanic battery, at one-third to one-fourth part of the expense of a first-rate regulator or an ordinary astronomical transit. A collateral advantage has been found to be, that the old transit clock, as now locked up in a closet and used only to regulate the observing clock, remains in a more equable temperature.

Major A. Strange, late Astronomical Assistant in the Great Trigonometrical Survey of India, has sent to the Society three papers:—

"On Testing the Vertical Axes of Altazimuth Instruments."

"On a Direct Method of Testing and Adjusting the Equipoise of Altazimuth Instruments."

"On a proposed Isolated Flange for Conical Axes."

It would be useless to attempt giving an abstract of these elaborate papers, relating, as they do, to instrumental details, and requiring the illustration of a series of figures.

Information has been received of the death of M. Daussy, Member of the Bureau des Longitudes at Paris, and an Associate of the Society.

RECENT PUBLICATIONS.

Astronomical Observations made at the Sydney Observatory in the year 1859. By W. Scott, M.A., Astronomer for New South Wales. Sydney, 1860. 8vo. pp. i. to xxiv. and 1 to 112.

In the *Monthly Notices*, vol. xix. p. 293, are printed some extracts from the first Annual Report to the Observatory Board, 22d Dec. 1858, giving an account of the establishment and the position of the Observatory. The Transit Circle arrived from England about the end of December 1858; but the regular observations were not commenced until June 1859.

It appears by the observations published in the *Monthly Notices*, vol. xx. p. 77, that the latitude and longitude of the Observatory were provisionally found to be Lat. $33^\circ 51' 41''\cdot 1$ S.; Long. $10^h 4^m 59^s\cdot 86$ W. The corrected values, as given by the Observations of Zenith Distances of *Nautical Almanac* Stars and the Observations of Moon-culminating Stars during the year 1859, are found to be Lat. $33^\circ 51' 40''\cdot 8$ N.; Long. $10^h 4^m 59^s\cdot 96$ W.

The greater part of the volume is occupied with Transit and Zenith-distance Observations of Stars; and from these are deduced the mean right ascensions and north polar distances for 1st January, 1859. It is from the internal evidence afforded by these that an estimate can be formed of the amount of reliance to be placed on the results which may hereafter proceed from the Observatory.

The causes of error are in a great measure of a temporary nature; such, for instance, as the changes in the piers of the instrument, owing to the contraction of the sandstone; but the results indicate also a permanent instrumental error, such as an irregularity in the form of the pivots. The errors of observation are not greater than those which occur in observatories of a high class, as those at Oxford and Cambridge, and are such as to disappear to a great extent when the mean of four or five observations is taken; but the instrumental errors are such that, although the circle may be regarded for some purposes as a useful instrument, yet it cannot be classed among instruments of the highest order, nor can its results compare in accuracy with those obtained at the Royal Observatory at the Cape of

Good Hope. It was therefore desirable to avoid as much as possible observing the same stars as had recently been, or would soon be observed, at the Cape of Good Hope. But, in the absence of information from thence, it was decided to observe, in addition to *Nautical Almanac* stars, only those stars of the 6th and 7th magnitudes which are given in the British Association Catalogue or in Lacaille's New Catalogue; and up to the end of 1859 the observations were limited to a space of 10° on each side of the zenith. But the equatoreal telescope, which has been ordered of Messrs. Merz and Son (7 inches French in aperture and 9 feet 8 inches focal length), and is in course of construction, when it arrives, may perhaps give a totally different direction to the efforts of the Observatory.

Taschenbuch für Mathematik, Physik, Geodäsie, und Astronomie. Von Dr. Rudolf Wolf, dritte umgearbeitete und erweiterte mit 22 Tabellen und 5 Figurentafeln ausgestattete Auflage, 12mo. Bern, 1860, pp. 1–269.

This little volume appears to be a most convenient handbook, comprising the utmost possible information for its bulk on the subjects to which it relates, and the author's name is a guarantee for the character of the work.

Memoria sobre el Eclipso de Sol de 18 *de Julio de* 1860. Por D. Francisco de Paula Marquez, Capitan de Navio de la Armada, y Director del Observatorio de Marina de S. Fernando. Publicada de Orden Superior. 8vo. Madrid, 1861.

The work contains an account of the Observations of the Eclipse, made at Oropesa, on the east coast of Spain, near the central line, by the Spanish Naval Commission under the command of D. F. Marquez, in company with the Portuguese Commission from Coimbra. It contains also an elaborate "Optical" theory of the Corona, Red Prominences, and other phenomena of the Eclipse, considered as arising from the diffraction and reflexion in our atmosphere of the light refracted at the border of the Moon's disk, and from the motion of the Moon.

Beobachtung der totalen Sonnen-Finsterniss vom 18 (6) *Juli,* 1860, *in Pobes.* Nach den Berichten der einzelnen Theilnehmer zusammengestellt von Otto Struve. Mit 3 Tafeln. (From the *Mém. de l'Acad. de St. Pét.* t. iv. 1861.)

The party from Pulkova who joined the Himalaya Expedition consisted of M. O. Struve, Dr. Winnecke, and the Portuguese Astronomer, Lieut. Oom, and the memoir contains an account of the observations of the Astronomer Royal, the three Pulkova Astronomers, and Herr C. Weiler, at or near Pobes, and of Herr Stenglein at Lodio, a few miles south of Bilbao.

Mémoire sur l'intégration des Equations différentielles relatives au Mouvement des Comètes, établies suivant l'hypothèse de la force répulsive definie par M. Faye, et suivant l'hypothèse d'un Milieu résistant dans l'espace. Par Jean Plana. (*Turin Memoirs,* t. xxi. 1861.)

This memoir, dated 12 Sept. 1861, replaces one with the same title presented to the Turin Academy, 26 May, 1861, the numerical results of which were erroneous, in consequence of an error of transcription in one of the formulæ. The conclusion arrived at is stated to be, that while the hypothesis of M. Faye gives results approaching those observed for the two periodic comets of 1205 days and 2718 days (Encke's and Faye's), a better agreement with the results of observation is obtained by the hypothesis of a resisting medium. The investigation relates exclusively to the motion of the centre of gravity of the comet.

M. Faye's hypothesis, referred to in his paper, *Comptes Rendus,* 4 March, 1861, consists in supposing that there is a repulsive force emanating from the incandescent surface of the Sun, and, like the attractive force, varying as the inverse square of the distance, but which, in consequence of the finite velocity of propagation, acts in a direction inclined to that of the radius vector.

Tabulæ Quantitatum Besselianarum quibus Apparentes Stellarum Positiones in Medias convertuntur, adhibitis Numeris Constantibus Pulcovensibus pro annis 1840 *ad* 1864 *computatæ.* Ed. O. Struve. 8vo. Pet. 1861.

The tables are based on the formulæ and numerical values of the constants of precession, nutation, and aberration, given

in Peters' well-known work, *Numerus Constans Nutationis*, &c., Pet. 1842.

They contain for the 25 years to which they relate the logarithms of the quantities A, B, C, D, and the quantity τ for 0^h Pulkova sidereal time of each day. The quantity E, which varies very slowly, is given only for the last day of each month. Besides the logarithms of A, B, C, D, there are given, in the cases where the rapid variation of the logarithms renders it necessary for accuracy, the natural values of B, C, D.

Arc du Meridian de 25° 20′ entre la Danube et la Mer Glaciale, mésuré depuis 1816 *jusqu'en* 1855. Sous la direction de C. de Tenner, Général d'Infanterie de l'Etat-Major Impérial de Russie, Chr. Hansteen, Directeur du Departement Géographique Royal de Norvège, N. H. Selander, Directeur de l'Observatoire Royal de Stockholm, et F. G. W. Struve, Directeur de l'Observatoire-Central-Nicolas de Russie. Ouvrage composé sur les différens Matériaux et rédigé par F. G. W. Struve. Publié par l'Académie des Sciences en St. Pétersbourg. Tome premier, Opérations géodésiques entre le Danube et le Golfe de Finlande, St. Pét. 1860. Tome deuxième, Opérations Géodésiques entre le Golfe de Finlande et la Mer Glaciale. St. Pét. 1857. Deux volumes, 4to. avec Atlas de 26 planches.

The introduction to vol. i. contains the general history of this great geodetical undertaking. The total arc, comprised between Fuglenœs, lat. 70° 40′ (near the North Cape), and Staro-Nekrassowka, lat. 45° 20′ (near the mouth of the Danube), is 25° 20′ in latitude. It is composed of 258 principal triangles, with 10 measured bases, not reckoning among the 258 triangles the triangles which effectuate the junction of the bases with the chain of triangles. The distance between the extreme points, measured on the great circle joining them, is 2700 versts = 2880 kilometers = 1552 geographical miles. The Observatory of Dorpat is about half-way between the extreme points, and may be considered as the meridian of the total arc.

The total arc is divided into two principal portions, a southern and a northern arc, meeting at the Island of Hogland in the Gulf of Finland; in fact, the triangles of the two arcs form two distinct series, having a common point at Mäki-Päälys in Hogland, but without any common side connecting the terminal triangles of the two arcs.

There are on the total arc 13 points where the azimuth and latitude have been astronomically determined. The Observatory of Dorpat is the only point the longitude whereof

has been determined with eminent precision, by the chronometric comparison in the year 1854, between Dorpat and Pulkova.

In a statistic and chronological point of view, disregarding the observations of latitude which were in part repeated at a posterior epoch; the total arc may be divided into seven parts, which are

Arc of	Between Latitudes.		Measured under direction of	In the Years
	° ′	° ′		
1. Bessarabia	45 20 —	48 15	M. de Tenner	1844–1852
2. Podolia and Volhynia	48 15	52 3	ditto	1835–1840
3. Lithuania	52 3	56 30	ditto	1816–1828
4. Baltic Provinces	56 30	60 5	M. Struve	1816–1831
5. Finland	60 5	65 50	ditto	1830–1851
6. Lapland	65 50	68 54	M. Selander	1845–1852
7. Finmark	68 54	70 40	M. Hansteen	1845–1850

and the history may be divided into four periods, embracing 1. The origin of the undertaking, and the operations of MM. de Tenner and Struve relating to the arcs of Lithuania and the Baltic Provinces, united into a single arc of 8° 2′. The period terminates in 1831.

2. The period 1830 to 1844 comprises the continuation of the meridian northwards to Tornea, latitude 65° 50′, and the preparations for the Southern continuation as far as the Dniester.

3. From 1844 to the end of the year 1851, comprising the continuation southwards to the Danube and northwards to the Arctic Ocean.

4. The supplementary operation posterior in date to 1851, intended partly to reduce to uniformity and a higher degree of perfection the data requisite, as well for the union of the different partial arcs, as for the utilisation of this arc for the determination of the figure of the Earth.

There is given, pp. cxli. to cxliii., a chronological catalogue of the different publications in the *Astronomische Nachrichten*, the *Memoirs* and *Bulletins of the Academy of St. Petersburg* and elsewhere, in relation to the measurement of the arc of 25° 20′.

The astronomically determined latitudes in the Russian-Scandinavian Arc of 25° 40′ are not, as in the English Ordnance Trigonometrical Survey, corrected for the deviations of the plumb-line due to the calculated attractions of the ine-

qualities of the surface in the neighbourhood of the Station. It appears that in the opinion of General de Schubert, this correction should have been made; and with a view thereto, there should be a careful levelling of all the astronomical stations, or at least of certain specified astronomical stations, on the arc. The question is discussed by M. Otto Struve in a paper in the *Bulletins of the Academy of St. Petersburg* ($\frac{8}{20}$ Feb. 1861), in which he maintains the contrary opinion, that this correction ought not to be made.

Astronomical Observations made at the Observatory of Cambridge. By the Rev. James Challis, M.A. &c. Vol. xix. for the years 1852, 1853, and 1854. 4to. Camb. 1861.

The volume contains the Observations made with the Transit and Mural Circle in the years 1852, 1853, and 1854, the Observations of Planets and Comets with the Northumberland Equatoreal in the same interval being reserved for separate publication with those of preceding years.

The major part of the observations of the three years are directed towards the determination of the places of stars, and more especially such as are included in the list of 8000 zodiacal stars, observations of which were commenced in 1849.

The observations of the Moon and Moon-culminating Stars were discontinued at the end of 1852. The Sun, the Planet *Neptune*, and the Minor Planets, were observed in that and the two following years. All these observations were compared calculated places, and if no Ephemeris was available for the purpose, the places were directly computed from elements of the orbits.

Astronomical and Meteorological Observations made at the Radcliffe Observatory in the year 1858. Under the Superintendence of Manuel J. Johnson, M.A., late Radcliffe Observer. Reduced and Printed under the Superintendence of the Rev. R. Main, M.A., Radcliffe Observer. Vol. xix. Published by order of the Radcliffe Trustees. 8vo. Oxford, 1861.

Instruments for Sale.

The Radcliffe Observer is empowered to offer for sale the Transit Instrument and Meridian Circle which have been in use since the commencement of Mr. Johnson's directorship till the present time, but which are now unnecessary on the establishment of the Carrington Transit Circle.

The Transit Instrument has an object-glass of 4 inches clear aperture, with a focal length of 8 feet, and is an excellent instrument of its class. Price 120*l.* without the piers.

The Meridian Circle, by Jones, is 6 feet in diameter, and its telescope, of the same focal length, has a clear aperture of 4 inches. It cost about 1000*l.* Price without its piers 300*l.*

The piers may be taken at a valuation at the discretion of the purchaser.

The Astronomer Royal has been requested by the Rev. George Fisher to state that Commander Mansell's Comet observations (see page 16) were computed by the senior boys of the Nautical School, under the direction of John Riddle, Esq., Head Master of the Nautical School.

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Printed by STRANGEWAYS and WALDEN, Castle St. Leicester Sq., and Published at the Apartments of the Society, December 9, 1861.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. XXII. *Dec.* 13, 1861. No. 2.

Dr. Lee, President, in the Chair.

Henry Worms, Esq., Park Crescent, Portland Place; and
Rev. John Sargent, 6 Bentinck Terrace, Regent's Park,

were balloted for and duly elected Fellows of the Society.

Grant for a Hill Observatory in India.

The following letter was received in answer to an application for the aid of Her Majesty's Government towards the establishment for a limited period, under the superintendence of Captain Jacob, of an Observatory in the neighbourhood of Bombay, at a considerable altitude above the sea.

Treasury Chambers,
8th August, 1861.

In reply to your application addressed to Lord Palmerston on the 24th June last, for a grant to the Royal Astronomical Society of 1000*l.* in aid of the proposed temporary maintenance of an observatory near Poonah, I am commanded by the Lords Commissioners of Her Majesty's Treasury to acquaint you that the sum of 1000*l.* having been voted in Parliament for the object described in your letter, My Lords will be prepared to issue the

amount in such manner as you may desire, on the understanding that the Society will see to the proper application of the fund thus placed at its disposal.

I have the honour to be, Gentlemen,

Your obedient servant,

(Signed) GEO. A. HAMILTON.

The President and Treasurer of the Royal Astronomical Society, Somerset House.

A letter was sent to his Lordship expressing the thanks of the Council for the promptness with which their application had been met.

The foregoing grant was announced by the President at the November Meeting, and should have been mentioned in the last number of the *Notices*.

On the Right Ascensions and Declinations of the Radcliffe Catalogue. By Dr. Wolfers.

(*Communicated by the Rev. R. Main.*)

The Radcliffe Trustees having presented to me the observations made at the Radcliffe Observatory, Oxford, vols. xviii. and xix., I have compared the places of stars contained in these two volumes with those contained in the *Tabulæ Reductionum*. Having combined these two series of differences with the earlier-obtained series (*Astr. Nachr.*, No. 1181), I have obtained the table of comparisons which I now send.

Excluding only the R.A. of the two polar stars α and δ *Ursæ Minoris*, the result of the comparison is

	J. — W.		
Number of Observations.	R.A.	Number of Observations.	Decl.
347	$+0^s.026$	288	$+0''.046$

Excluding, moreover, the R.A. of the circumpolar stars α *Ursæ Majoris*, γ *Ursæ Majoris*, and β *Ursæ Minoris*; further excluding the R.A. of α *Geminorum*, because in the *Tab. Red.* there is given the mean of the R.A. of α^1 and α^2 *Geminorum*, but in the observations the R.A. of each of them, the difference of the two R.A. given in the *Astr. Jahrbüch* being not very accurate, the result of the whole comparison is

	J. — W.		
Number of Observations.	R.A.	Number of Observations.	Decl.
326	$+0^s.017$	288	$+0''.046$

To the R.A. of α *Canis Majoris* the correction of M. Peters is applied; and these differences being reduced to the year 1860,

J. denotes the co-ordinates observed at Oxford, W. denotes the co-ordinates given in the *Tab. Red.*

The Right Ascensions and Declinations of Fundamental Stars observed at the Radcliffe Observatory, compared with those contained in the Tabulæ Reductionum.

Name of Star.	Number of Observations.	J. — W. R.A.	Number of Observations.	J. — W. Decl.
		s		″
α Andromedæ ...	4	+0·02	5	+0·7
γ Pegasi	9	−0·04	6	+2·6
α Cassiopeiæ ...	3	+0·09	4	−0·4
α Arietis	6	−0·02	3	+1·5
α Ceti	9	+0·01	4	+0·4
α Persei	5	−0·06	3	−0·2
α Tauri	16	−0·02	9	+0·2
α Aurigæ ...	5	−0·01	6	−0·6
β Orionis ...	8	0·00	7	+0·4
β Tauri	5	+0·05	6	+2·5
α Orionis ...	8	+0·02	5	+1·4
α Canis Majoris...	8	−0·02	20	−0·4
α Geminorum ...	10	+0·12	8	+1·8
α Canis Minoris...	11	+0·03	9	+0·6
β Geminorum ...	16	−0·01	10	+0·3
α Hydræ... ...	9	+0·06	7	−2·1
α Leonis... ...	15	+0·01	12	+1·1
α Ursæ Majoris...	5	+0·32	12	+0·6
β Leonis... ...	9	+0·08	6	−0·3
β Virginis ...	9	+0·13	5	−0·4
γ Ursæ Majoris...	5	+0·21	2	+0·2
α Virginis ...	12	+0·08	14	−1·3
η Ursæ Majoris...	10	+0·06	2	−0·8
α Boötis	6	+0·02	2	+0·4
$α^1$ Libræ... ...	1	+0·04	4	−0·4
$α^2$ Libræ... ...	10	+0·10	3	−0·6
β Ursæ Minoris...	1	−0·26	5	−0·1
α Coronæ ...	9	+0·01	3	−0·7
α Serpentis ...	10	0·00	3	−0·4
α Scorpii... ...	12	+0·14	7	−0·2
α Herculis ...	6	−0·10	1	−0·2
α Ophiuchi ...	10	−0·02	8	−0·1
γ Draconis ...	5	+0·03	4	−0·8
α Lyræ	11	+0·07	8	−0·4
γ Aquilæ... ...	6	0·00	3	−0·7

Name of Star.		Number of Observations.	J. — W. R.A.	Number of Observations.	J. — W. Decl.
			s		″
α Aquilæ	...	10	−0·05	9	+0·3
β Aquilæ	...	4	+0·02	4	−0·2
α¹ Capricorni	...	—	—	2	−1·8
α² Capricorni	...	5	+0·01	5	−2·8
α Cygni ...	...	8	−0·01	6	−2·4
α Cephei...	...	11	−0·07	7	+0·9
β Cephei...	...	4	−0·11	10	+0·2
α Aquarii	...	9	−0·06	2	−1·0
α Piscis Australis		8	−0·02	8	−0·4
α Pegasi ...	...	4	−0·12	6	−0·3
α Ursæ Minoris...		8	−0·24	4	0·0
δ Ursæ Minoris...		4	+0·48	9	+1·8

Berlin, November 30, 1861.

On the Secular Acceleration of the Moon's Mean Motion. By A. Cayley, Esq. (Abstract.)

The inclination and excentricity of the Moon's orbit, and *à fortiori* the variation of the position of the ecliptic, and the latitude of the Sun, are neglected; and the longitudes are measured from a fixed point in the ecliptic. The notation is in the present Abstract explained in so far only as it presents any peculiarity. I take

n, the actual mean motion of the Moon at a given epoch;

viz., it is assumed that the mean longitude at the time t is $\epsilon + n t + n_2 t^2 +$ &c. where ϵ, n, n_2, &c. are absolute constants; and, moreover,

a, the calculated mean distance of the Moon;

that is, $n^2 a^3$ is the sum of the masses of the Earth and Moon; a is, therefore, an absolute constant.

$$m, = \frac{n'}{n}, \text{ is an absolute constant.}$$

The Sun is considered as moving according to the law of elliptic motion in an orbit the excentricity whereof is $e' + \delta e'$, or $e' + f' t$, where e', f', are absolute constants.

In the expression of the disturbing function the Sun's mass is taken to be $= n'^2 a'^3$, or, what is the same thing, $= m^2 n^2 a'^3$.

Then r, v, being the radius vector and longitude of the Moon, and taking the usual approximate expression of the disturbing function, the equations of motion are

$$\frac{d}{dt}\frac{dr}{dt} - r\left(\frac{dv}{dt}\right)^2 + \frac{n^2a^3}{r^2} = m^2n^2a'^3\frac{r}{r'^3}\left(\frac{1}{2} + \frac{3}{2}\cos 2v - 2v'\right),$$

$$\frac{d}{dt}\frac{r^2dv}{dt} \qquad = m^2n^2a'^3\frac{r^2}{r'^3}\left(\quad - \frac{3}{2}\sin 2v - 2v'\right);$$

or writing

$$\frac{r}{a} = \varrho, \quad \frac{r'}{a'} = \varrho',$$

we have

$$\frac{d}{dt}\frac{\partial\varrho}{dt} - \varrho\left(\frac{dv}{dt}\right)^2 + \frac{n^2}{\varrho^2} = m^2n^2\,\mathrm{P},$$

$$\frac{d}{dt}\left(\varrho^2\frac{dv}{dt}\right) \qquad = m^2n^2\,\mathrm{Q},$$

where, for shortness,

$$\mathrm{P} = \frac{\varrho}{\varrho'^3}\left(\frac{1}{2} + \frac{3}{2}\cos 2v - 2v'\right),$$

$$\mathrm{Q} = \frac{\varrho^2}{\varrho'^3}\left(\quad - \frac{3}{2}\sin 2v - 2v'\right).$$

The notation is then changed by writing $\varrho' + \delta\varrho'$, $v' + \delta v'$, in the place of ϱ', v'; using henceforward ϱ', v', to denote the elliptic values of the solar co-ordinates, as calculated with the constant excentricity e'; and, moreover, $\varrho + \delta\varrho$, $v + \delta v$, in the place of ϱ, v; using henceforward ϱ, v, to denote the values of the lunar co-ordinates obtained from the equations of motion by writing therein ϱ', v', instead of the complete values $\varrho' + \delta\varrho'$, $v' + \delta v'$. Then putting

$$\delta\mathrm{P} = \frac{d\mathrm{P}}{\delta\varrho}\delta\varrho + \frac{d\mathrm{P}}{dv}dv + \frac{d\mathrm{P}}{d\varrho'}\delta\varrho' + \frac{d\mathrm{P}}{dv'}dv',$$

with a like value for $\delta\mathrm{Q}$, and observing that the equations of motion are satisfied when $\delta\varrho$, δv, $\delta\varrho'$, $\delta v'$, are neglected, we have

$$\frac{d}{dt}\frac{d\delta\varrho}{dt} - \delta\varrho\left(\frac{dv}{dt}\right)^2 - 2\varrho\frac{dv}{dt}\frac{d\delta v}{dt} - \frac{2n^2}{\varrho^3}\delta\varrho = m^2n^2\delta\mathrm{P},$$

$$\frac{d}{dt}\left(\varrho^2\frac{dv}{dt} + 2\varrho\delta\varrho\frac{dv}{dt}\right) \qquad = m^2n^2\delta\mathrm{Q};$$

or, integrating the second equation, and by means of such integral changing the form of the first equation, we have

$$\frac{d^2\delta\varrho}{dt^2}+n^2\delta\varrho=\left\{n^2+\frac{2n^2}{\varrho^3}-3\left(\frac{dv}{dt}\right)^2\right\}\delta\varrho+m^2n^2\left\{\delta\mathrm{P}+\frac{2}{\varrho}\frac{dv}{dt}\left(\mathrm{C}+\int d\mathrm{Q}\,dt\right)\right\},$$

$$\frac{d\delta v}{dt}=\qquad -\frac{2}{\varrho}\frac{dv}{dt}\delta\varrho+\frac{m^2n^2}{\varrho^2}\left(\mathrm{C}+\int\delta\mathrm{Q}\,dt\right),$$

where C is to be determined by the condition that $\frac{d\delta v}{dt}$ may contain no constant term (for otherwise nt would not be the whole term varying directly as the time, in the longitude $v+\delta v$). The values of ϱ', v', $\delta\varrho'$, $\delta v'$, are given by the theory of elliptic motion, and those of ϱ, v, by the ordinary lunar theory, in which the excentricity of the solar orbit is treated as a constant; the integration of the last-mentioned equations leads to the values of $\delta\varrho$, δv, and then the radius vector and longitude of the moon are $a\,(\varrho+\delta\varrho)$, $v+\delta v$, respectively.

We, in fact, have

$$\begin{array}{rll}
\frac{1}{\varrho} = 1 + \frac{1}{6}m^2 & & \\
+\frac{3}{2}m^2e' & \cos g' & \\
+ m^2 & \;\;,, & 2\tau \\
+\frac{7}{2}m^2e' & \;\;,, & 2\tau-g' \\
-\frac{1}{2}m^2e' & \;\;,, & 2\tau+g' \\
v = nt+\epsilon & & \\
-3me' & \sin g' & \\
+\frac{11}{8}m^2 & \;\;,, & 2\tau \\
+\frac{77}{16}m^2e' & \;\;,, & 2\tau-g' \\
-\frac{11}{8}m^2e' & \;\;,, & 2\tau+g'
\end{array}$$

$(g' = c'mnt + \text{const.} \qquad 2\tau = (2-2m)\,nt + \text{const.})$

$$\frac{1}{\varrho'} = \quad 1$$
$$\qquad + e' \cos g'$$
$$v' = \quad n't + \epsilon$$
$$\qquad + 2e' \sin g'$$
$$\delta \frac{1}{\varrho'} = \quad 1 \qquad t \cos g'$$
$$\qquad + 2e' \qquad ,, \; 2g'$$
$$\delta v' = \quad 2 \qquad t \sin g'$$
$$\qquad + \frac{5}{2} e' \qquad ,, \; 2g'$$

where, instead of $\delta e' = f' t$, $\delta e'$ has been put $= t$, a simplification which is employed throughout the working, the factor f' being restored in the final results.

The values in the first instance obtained for $\delta\varrho$, δv, are

$\delta\varrho = f'$ into as follows, viz.:

$\frac{3}{2} m^2 e' t$			$+ \overbrace{\qquad\qquad}^{n^{-1} \times}$		
$+ \frac{3}{2} m^2$	$t \cos g'$		$3 m^3$	$\sin g'$	
$+ 5 m^2 e'$	,,	2τ	$- \frac{203}{12} m^2 e'$	,,	2τ
$- \frac{7}{2} m^2$	,,	$2\tau - g'$	$+ \frac{61}{24} m^2$	,,	$2\tau - g'$
$+ \frac{1}{2} m^2$	,,	$2\tau + g'$	$- \frac{91}{14} m^2$	,,	$2\tau + g'$
$+ \frac{9}{2} m^2 e'$	,,	$2g'$	$- 18 m^3 e'$	,,	$2g'$
$- 17 m^2 e'$	,,	$2\tau - 2g'$	$+ \frac{85}{6} m^2 e'$	,,	$2\tau - 2g'$
0	,,	$2\tau + 2g'$	$- \frac{3}{4} m^2 e'$	,,	$2\tau + 2g'$

and

$\delta v = f'$ into as follows, viz.:

		$- \frac{3}{2} m^2 n e' t^2$
$- 3$	$t \sin g'$	$+ \overbrace{-3 + 6m^2}^{n^{-1} \times} \cos g'$

$-\frac{55}{8}m^2e'$	$\sin 2\tau$	$-\frac{74}{3}m^2e'$	$\cos 2\tau$
$+\frac{77}{16}m^2$	,, $2\tau-g'$	$+\frac{215}{48}m^2$	,, $2\tau-g'$
$-\frac{11}{16}m^2$	,, $2\tau+g'$	$-\frac{257}{48}m^2$	,, $2\tau+g'$
$-\frac{9}{2}me'$	,, $2g'$	$\left(-\frac{9}{4}+18m^2\right)e'$	,, $2g'$
$+\frac{187}{8}m^2e'$	,, $2\tau-2g'$	$+\frac{2239}{96}m^2e'$	,, $2\tau-2g'$
0	,, $2\tau+2g'$	$-\frac{33}{32}m^2e'$	,, $2\tau+2g'$

where it is to be noticed that the terms t cos arg. and t sin arg. arise from the substitution of $e'+f't$ for e' in the coefficients of the terms cos arg. and sin arg. in the ordinary values of ϱ and v. The new periodic terms sin arg. in $\delta\varrho$ and cos arg. in δv agree as to the arguments g', 2τ, $2\tau-g'$, $2\tau+g'$, with those obtained by Prof. Adams; those for the other arguments $2g'$, $2\tau-2g'$, $2\tau+2g'$, do not contribute to the formation of the term in m^4 of the acceleration.

Starting from the foregoing expressions of $\delta\varrho$ and δv, and proceeding to calculate the non-periodic parts as far as m^4, the results are found to be

$$\delta\varrho=\left(\frac{3}{2}m^2-\frac{1973}{32}m^4\right)e'f't,$$

where the number $\frac{1973}{32}$ is made up

$$-\frac{1973}{32}=\frac{381}{8}-\frac{495}{32}-\frac{15}{4}-\frac{647}{32}-\frac{1455}{16}+\frac{675}{32};$$

and

$$\delta v=\left(-\frac{3}{2}m^2+\frac{3771}{64}m^4\right)ne'f't^2,$$

where the number $\frac{3771}{64}$ is obtained by means of the before-mentioned number $\frac{1993}{32}$; but replacing this number $\frac{1973}{32}$ by its component terms, the number $\frac{3771}{64}$ is made up

$$\frac{3771}{64}=-\frac{381}{8}+\frac{495}{32}+\frac{15}{4}+\frac{647}{32}+\frac{1455}{16}-\frac{675}{32}+\frac{275}{16}+\frac{45}{16}-\frac{1455}{64}.$$

It is hardly necessary to remark that, f'^2 being neglected, $2e'f'\,t=(e'+f'\,t)^2-e'^2$, and $\therefore\ e'f't^2=\int[(e'+f'\,t)^2-e'^2]\,dt$, where $(e'+f'\,t)^2-e'^2$ is what is commonly represented by $(e'^2-\mathrm{E}'^2)$. The value of m is not that made use of by Prof. Adams; in fact,—

$$m\ (\text{Adams}) = m\ \left\{1+\left(\frac{3}{2}m^2-\frac{3771}{64}m^4\right)2\,e'f'\,t\right\}$$

but in the terms multiplied by f' the two values of m may be considered as identical, hence the foregoing expression of δv, in the notation of Prof. Adams, is

$$\delta v = \left(-\frac{3}{2}m^2+\frac{3771}{64}m^4\right)\int\left(e'^2-\mathrm{E}'^2\right)n\,dt$$

the result obtained by him. The number $\frac{1973}{32}$, the coefficient of m^4 in the expression $\delta\varrho$, does not occur explicitly in his memoir, but is, in fact, deducible from the value there given for the reciprocal of the radius vector. The present abstract gives a complete outline of the method of investigation, and it was thought better to omit altogether the details of the working rather than present them in an incomplete manner.

The Transit of Mercury, Nov. 11, 1861.

(*Extract of a Letter from Father Secchi to the Astronomer Royal, dated Rome, Nov.* 16, 1861.)

The passage of *Mercury* on the solar disk has been observed here under very good circumstances, but almost by a miracle, because the sky was all overcast by clouds. Some details will be found in the *Comptes Rendus*, and more yet in the *Astronomische Nachrichten.* But it will not displease the Astronomical Society to know the principal results; they are the following:—

	h	m	s
Interior contact, Sid. T. Rome ...	13	35	6·29
Or M.T. Rome	22	9	9·45
Centre (estimated), Sid. T.	13	36	10·19
Exterior contact, Sid. T.	13	37	14·09

The air was exceedingly calm, and the rupture of the narrow ring was made with the utmost tranquillity, leaving two very sharp cusps. The exterior edge of the Sun appeared in the narrow thread of light, before the rupture, more faint

a good deal than the part of the Sun at the opposite point of the diameter of the planet. The blackness of the planet appeared greater a good deal than the usual nuclei of the spots, and its termination persuaded me that the nuclei are really badly terminated, and that there is a real diffusion of matter in their borders. In the intervals left between the clouds, during the passage, I measured a great many distances and positions of the planet from the edge of the Sun's disk; and I made, also, 9 double measures of the diameter of the planet. The result of these is $=9''\cdot077$, with probable error $=0''\cdot189$. It is remarkable that the duration of the passage gives for this diameter $9''\cdot165$. This value is different from that given in the tables. A year ago I obtained from some measures a diameter even smaller—that is, $8''\cdot91$. I propose to take a few more measures of this element; but it is rather difficult, on account of the termination of *Mercury's* disk, which is always very bad, and seems to be very faint at the edges.

A new discussion of my magnetical observations compared with a series of electrical atmospherical observations have led me to admit a real connexion between this electricity, and the variations of at least the horizontal intensity. In many things, I think, M. Lamont is right; and what he has suggested on this account I believe him to have demonstrated and seen directly.

The Transit of Mercury, November 11, 1861, *observed at Malta.* By W. Lassell, Esq.

At No. 9, Piazzi Stierna, Via Torre, Malta, approximate longitude $58^m\ 2^s$ east of Greenwich, latitude $35°\ 54'\ 46''$ north, 1861, Nov. 11th, I observed the emersion, or egress, and part of the transit of *Mercury* over the Sun. The best telescope I had at hand was a very sharply-defining Gregorian of 4·7 inches aperture; power used, 78. I first pointed the telescope at about 19·50 Stierna mean time. The planet, being considerably advanced on the disk, appeared perfectly well defined, round, and black. I watched the phenomenon from time to time until about 22^h; after which I observed it uninterruptedly until its disappearance. I had, however, no means suitable for making any accurate measures; but I was filled with admiration, throughout, of the exquisite beauty of the vision. The limb of the Sun and the disk of the planet were far more sharp and beautiful than I have ever seen them with equal power, and within $1\frac{1}{2}$ to 3 hours of the horizon.

Notwithstanding that the heat of the Sun was so great as to make a shield necessary for the exposed part of my person (though I was generally well protected by a verandah), yet the image was, with occasional slight disturbances, as sharp as can be conceived, and afforded a striking contrast to all I have seen before.

I scrutinised the planet well throughout its transit, but could not be sure of any peculiarity. I repeatedly *fancied* it a little elliptical, but I do not believe in the reality of the appearance.

The times are given in Stierna mean time; they were noted with a duplex watch, compared with a standard mean time clock, accurately corrected and rated by sextant observations.

At $22^h\ 15^m\ 57^s{\cdot}1$ the planet was estimated to be just its own diameter from the Sun's limb.

At $22^h\ 16^m\ 13^s{\cdot}5$ it was clearly within one diameter.

At $22^h\ 18^m\ 5^s{\cdot}9$, first contact. Shortly after, the planet seemed momentarily drawn out towards the limb, pear-like.

At $22^h\ 18^m\ 53^s{\cdot}5$ the Sun's limb bisected the planet. No distortion whatever. Shortly afterwards I had a momentary impression of the lengthening out of the diameter which was a tangent to the Sun's limb, or which had just passed it.

At $22^h\ 20^m\ 21^s{\cdot}5$, last contact, *i. e.* the first moment that I was sure that the planet was no more to be seen.

It has rarely been my lot to observe an astronomical phenomenon with circumstances so favourable and pleasant.

I have much pleasure in stating that I have erected the 4-foot equatoreal telescope on a very excellent site, across the Quarantine Harbour from Valetta, and nearly north of it, within a short distance of Fort Tigné.

A boundary wall, inclosing an area twenty yards square, in the centre of which the telescope stands, and a sufficiently capacious laboratory adjacent, are on the point of completion. The observing tower is in process of erection, and I hope very shortly to commence operations.

Observations of the Transit of Mercury, November 11, 1861, *made at the Observatory, Durham.* By Prof. T. Chevallier.

The weather was very favourable, at Durham, for observing the transit of *Mercury* on the 11th of November. At sunrise the eastern part of the sky was almost cloudless, and continued so till the emersion of the planet. The Sun's limb, however, in consequence of his low altitude and the state of the atmosphere, was very undulating.

Mercury was seen upon the Sun's disk immediately after sunrise, his appearance as a round black spot contrasting strongly with that of some ordinary spots on the Sun's surface.

The instruments used, in different rooms, were the Northumberland Equatoreal, of 7 feet 4 inches focal length and 5 inches aperture, and the Fraunhofer Equatoreal, of 8 feet 3 inches focal length and 6·5 inches aperture.

The internal and external contacts were observed as follows, in Durham sidereal time:—

	Northumberland Telescope. Prof. Chevallier.	Fraunhofer's Telescope. Mr. A. Marth.
	h m s	h m s
Internal contact ...	12 38 52·68	12 38 54·0
External contact ...	12 40 53·61	12 40 59·0

Each of these observations was difficult, in consequence of the undulations of the Sun's limb. An instant before the internal contact, the thin curved line of light between the planet and the Sun's limb seemed to break up, by the sudden filling up of the two cusps by a black space. This appearance was, no doubt, occasioned by the tremulous motion affecting the Sun's limb. The exact time of the external contact was rendered uncertain from the same cause.

The times, computed from Le Verrier's Tables by the formulæ given by Dr. Schjellerupp (*Astronomische Nachrichten*, No. 1286), are,

	Durham Sid. Time.
	h m s
Internal contact ...	12 38 55·12
External contact ...	12 41 10·60

Mr. Marth made the following observations of the difference of R.A. and declination of the Sun and planet, with a wire micrometer, each observation in R.A. being made on five wires, and five different measures having been taken of the difference of declination of *Mercury* and the Sun's northern limb:

Durham Sid. Time, Nov. 11.	Greenwich M.T.	Diff. of R.A. ☿ − ☉ corrected for Refraction and Proper Motion.	No. of Obs.	Corrected for Parallax.	Computed from Schjellerupp.	C—O.
h m s	h m s	s		s	s	s
11 58 22·9	20 38 49·5	−11·192	2	−11·308	−11·558	−0·25
12 5 8·0	45 33·4	−13·770	2	−13·883	−14·111	−0·23
28 16·7	21 8 38·4	−22·871	2	−22·971	−22·886	+ ·08
		Diff. of Decl. ☿ − ☉ N. Limb.	No. of Measures.	Corrected for Parallax.		
12h 21m 5s·4	21h 1m 28s·2	−2′ 6″·96	5	−2′ 3″·45	−1′ 59″·07	+4″·38

Observations of the Transit of Mercury, November 11, 1861, *at and near Liverpool.*

(*Communicated by Mr. Hartnup.*)

Observed by Mr. Hartnup, at the Liverpool Observatory, with the Equatoreal Refractor, aperture reduced to 4 inches, power 288, parallel wire micrometer.

By mean of 6 measures, equatoreal diameter = $10''\cdot09$
By mean of 6 measures, polar diameter = $9\cdot72$

The tremor was great, but the observations were taken with great care.

Egress.

	h m s	
Interior contact......	21 19 14·40	G.M.T.
Exterior contact ...	21 21 25·74	

The time was taken from the sidereal clock, which was $3^s\cdot33$ fast. The fine line of light appeared broken at $12^h 33^m 9^s$, but it instantly united again, and between 9^s and 20^s it broke and united several times; after 20^s the separation remained permanent. I have taken $14^s\cdot5$ as the most probable time of interior contact. Contrary to expectation, the last contact was observed with less difficulty than the first; the separation of the planet from the Sun's limb was instantaneous, and may, I think, be depended on to one second of time.

Egress observed by John Joynson, Esq., at Waterloo, near Liverpool:—

	h m s	
Interior contact ...	21 19 14·5	G.M.T.
Exterior contact...	21 21 9·5	

Latitude 53° 28′ 24″ N. Longitude 3° 1′ 44″ W.

Observed with a refractor of 3½ inches aperture and 50 inches focal length. The time was taken from a chronometer, the error of which was obtained from the Liverpool Observatory.

Egress observed by Matthew Jee, Esq., at Edge Hill, Liverpool:—

	h m s	
Interior contact ...	21 20 0	G.M.T.
Exterior contact...	21 21 20	

Latitude 53° 24′ 27″ N. Longitude 11′ 49″·4 W.

Observed with a Dollond's refractor, $2\frac{1}{8}$ inches aperture; power 80. The time was taken from the seconds clock in the office-window of the Magnetic Telegraph Company. This clock is controlled from the Liverpool Observatory.

The Transit of Mercury, November 11, 1861, *observed at Grantham.* By J. W. Jeans, Esq.

Lat. 52° 54′ 52″ N. Long. 0° 39′ 0″ W.

Morning fine, but rather hazy; a good many light clouds; wind moderate, and atmosphere very tremulous; vision at times good. The first observation I consider very fair, the last rather uncertain; telescope 5 feet focal length, achromatic, of 4 inches aperture, reduced to 2 inches; power 80. I was rather impressed with the idea that the figure of *Mercury* was not quite round, but slightly elongated, and that there was also a slight ashy light on his eastern limb. At best visions the outline of the planet was sharp, and the impression of ellipticity doubtful; no appearance of atmosphere; clock corrected by transit of δ *Leonis* the same morning, and by Fomalhaut and Markab the previous evening.

	h m s	
First break (pretty good)...	12 42 38·03	Apparent Local Sid. Time.
Last contact (middling) ...	12 44 44·03	

Grantham, December 5, 1851.

Observations of the Transit of Mercury, November 11, 1861. By Joseph Baxendell, Esq.

The following observations were made at Mr. Worthington's Observatory, the instrument used being the equatoreally-mounted achromatic of 5 inches aperture and 70 inches focal length. A power of 126 was first applied; but, owing to the unsteadiness of the atmosphere at so low an altitude, micrometrical measurements of the diameter of *Mercury* were found to be quite impracticable. Two measures of the planet's position on the Sun's disk were taken under a power of 68, but a light cirrous cloud was passing slowly over the Sun at the time, and the images were still very tremulous. The mean result, corrected for refraction and parallax, was as follows:—

At $2^{h}\,14^{m}\,10^{s}\!\cdot\!2$ G.M.T. App. R.A. of *Mercury* = App. R.A. of Sun − $20^{s}\!\cdot\!74$

App. N.P.D. of *Mercury* = App. N.P.D. of Sun − 14′ 14″·5

A few minutes before the end of the transit the cloud passed away, and the definition of the planet and of the Sun's limb improved considerably, and the internal and external contacts were observed very satisfactorily.

The internal contact took place at	$21^h\ 19^m\ 8^s{\cdot}68$	G.M.T.
The external ditto	21 21 22·80	"

When the planet was about one-fourth or one-third of its own diameter from the Sun's limb, its form was observed to change slightly; and at the moment of internal contact it was decidedly egg-shaped, the small end of the egg being next to the Sun's limb. The only other feature observed worthy of notice was the excessive *blackness* of the planet, as compared with the nuclei of the spots then visible on the solar disk.

In connexion with the apparent alteration of form of the planet, I may perhaps be allowed to give an extract from my journal, describing a similar appearance observed by my friend Mr. S. W. Williamson, of Cheetham Hill, and myself, on the occasion of the transit of *Mercury* which occurred Nov. 9th, 1848. The telescope employed was an excellent equatoreally-mounted achromatic, of $3\frac{1}{4}$ inches aperture and 42 inches focal length, belonging to Mr. Williamson, and the image of the Sun was thrown on a screen. This image was very well defined, and exhibited the usual features of the solar surface with great distinctness:—

"At the ingress of the planet a remarkable distortion of its image took place. When the planet had advanced nearly its own diameter on the Sun's disk, the image, instead of immediately assuming a full circular figure, gradually lengthened out on the following side into a pear-like form, until the planet had advanced about one-and-a-half of its own diameter on the Sun's disk, when the projecting part disappeared instantaneously, and the Sun's light closed round the planet, exhibiting it removed a very sensible distance from the limb of the Sun."

As the apparent diameter of *Mercury*, when on the sun's disk, is probably diminished by the effect of irradiation, the alteration of its form, on approaching or leaving the limb, as noticed by some observers, may perhaps be due to the diminished effect of irradiation consequent upon the rapidly diminishing intensity of the Sun's light near the limb, and to the greater susceptibility of some eyes than others to the effects of irradiation; and I may remark that, to my own eye, the degradation of the light of the Sun's disk near the border, whether seen directly through the telescope or projected on a screen, is always very strikingly evident.

Manchester, Dec. 12, 1861.

On the Elements of the Variable Star R *Sagittæ.*
By Joseph Baxendell, Esq.

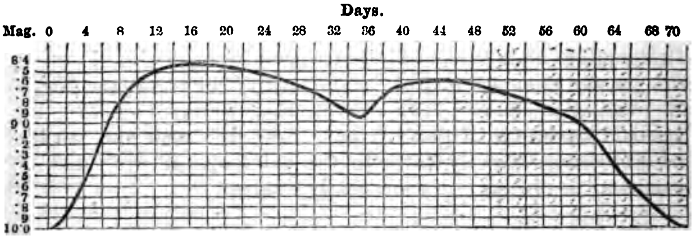
This star was discovered to be variable in October, 1859; and in a notice of it which I communicated to the Physical Section of the Manchester Literary and Philosophical Society, on the 5th January, 1860, its period was stated to be about 74 days, and its range of variation to be from the 9·8 magnitude at minimum to the 8·4 magnitude at maximum. The observations which I have since made have, however, enabled me to determine its elements with much greater accuracy than could be expected in a first approximation, and have also shown that it merits attention as being one of the very few but interesting variables, the light-curves whereof exhibit a distinctly marked *secondary* minimum. Many of the variables occasionally exhibit decided deviations from the ordinary course of their changes; but the cases are very rare in which a secondary minimum forms a permanent feature in the curves laid down from observations extending over several successive periods.

During the two years which have elapsed since I first noticed the variability of R *Sagittæ*, I have obtained the following determinations of the times of nine of its principal minima:—

1. 1859, Oct. 27	6. 1860, Dec. 27
2. 1860, Jan. 7	7. 1861, May 17
3. „ May 31	8. „ July 25
4. „ Aug. 7	9. „ Oct. 8
5. „ Oct. 19	

Treating the equations formed from these data by the method of least squares, I find that the

Epoch = 1860, Oct. 17·13
Period = 70·88 days



Light-curve of R *Sagittæ.* Period = 70·88 days.

Calculating the times of the minima by means of these elements, and comparing the calculated with the observed results, we have

	C – O.		C – O.
	days.		days.
1.	+ 1·73	6.	+ 0·01
2.	+ 0·61	7.	+ 0·77
3.	– 2·63	8.	+ 2·65
4.	+ 0·25	9.	– 1·47
5.	– 1·87		

These differences show that the variations in the length of the period of R *Sagittæ* are confined within moderate limits, and that this star may be ranked in the class of moderately regular variables.

Using the mean period of 70·88 days in combining all the observations made in the different phases of the star's changes, and projecting the mean results in the usual way, I find, from the curve thus obtained, that the principal maximum, the secondary minimum, and the secondary maximum, follow the principal minimum in 17, 35, and 44 days respectively. It appears, therefore, that the interval between the principal and the secondary minimum is almost exactly one-half of the whole period, precisely as in the case of the well-known double-period variable, *β Lyræ*.

The mean magnitude at the principal minimum = 10·00
,, maximum = 8·45
secondary minimum = 8·95
,, maximum = 8·60

The lowest minimum yet observed is 10·3, and the highest maximum 8·3; the greatest range of variation is, therefore, 2·0 magnitudes.

The mean place of the star for 1860·0 is

R.A. $20^{h}\ 7^{m}\ 40^{s}$; Decl. $16^{\circ}\ 18'{\cdot}3$ N.

Manchester, Dec. 9, 1861.

On the Variable Star R *Vulpeculæ.* By G. Knott, Esq.

R *Vulpeculæ.* Piazzi xx. 457. My earliest observations of this variable were made on the 7th, 9th, and 10th of September, when it shone as a star of the 9·3 magnitude. Bad weather and absence from home prevented another observation till the 26th of the month, when, to my surprise, I found it considerably fainter, and of the 11·7 magnitude. Since that date I have

kept the star pretty constantly in view; and the discussion and projection of my observations give October 27th as the epoch of *minimum*, just two days prior to the date of probable *maximum*, as given in Mr. Pogson's ephemeris. The magnitude at minimum appears to have been about 13·6.

As this is the first communication I have had the honour of submitting to the Astronomical Society, it will probably be deemed desirable that I should briefly describe my instrument and method of observing variable stars.

My Observatory is furnished with a 9-foot equatoreal, the object-glass by Messrs. Alvan Clark and Sons, and of 7⅓ inches aperture. It was formerly in the possession of the Rev. W. R. Dawes, and was very favourably spoken of by him—a sufficient guarantee of its quality. I usually employ an excellent positive eyepiece, constructed for me by Mr. Dollond; it has a large field, and gives a magnifying power of 60, as determined by measuring the emergent pencil. Higher magnifiers are occasionally employed.

In observing and discussing observations of variable stars, I have adopted Mr. Pogson's methods, as also his magnitude-scale (Argelander's extended). I am largely indebted to him, not only for his interesting and important papers in the *Astronomische Nachrichten* and the *Monthly Notices*, but also for several valuable hints in one or two personal communications with which he has favoured me. In all probability I am not the only amateur who is eagerly expecting his promised *Variable Star Atlas.*

Observations of Comet II. 1861, *taken with the Equatoreal of the Liverpool Observatory.* By J. Hartnup, Esq.

1861.	G.M.T. h m s	Comet's R.A. h m s	Log. $\frac{p}{P}$	Comet's N.P.D. ° ′ ″	Log. $\frac{q}{P}$	Stars of Comp. B.A.C.
July 3	10 44 32·7	9 42 13·06	+8·950	24 5 59·1	−9·7407	3496
3	11 21 16·0	9 44 3·75	+8·910	24 2 49·5	−9·7955	,,
4	10 54 4·6	10 50 43·43	+8·999	23 5 31·0	−9·6858	3647
4	11 25 20·0	10 52 4·32	+8·985	23 5 33·0	−9·7790	,,
4	11 56 34·8	10 53 25·01	+8·962	23 5 38·1	−9·8644	,,
5	11 8 34·1	11 46 10·28	+8·996	23 40 24·6	−9·5207	3968
5	11 29 11·1	11 46 50·71	+8·993	23 41 20·6	−9·5831	,,
5	11 49 48·5	11 47 31·40	+8·987	23 42 20·9	−9·6337	,,
6	10 3 56·4	12 25 23·85	+8·938	24 54 1·5	−9·0806	4276
6	10 24 23·6	12 25 53·65	+8·953	24 55 15·0	−9·2173	,,
6	10 44 50·5	12 26 23·61	+8·963	24 56 30·5	−9·3213	,,
7	10 24 25·2	12 55 52·79	+8·909	26 26 4·5	−9·1219	4300
7	10 54 53·7	12 56 24·84	+8·931	26 28 3·7	−9·2909	4276

1861.	G.M.T. h m s	Comet's R.A. h m s	Log. $\frac{p}{P}$	Comet's N.P.D. ° ′ ″	Log. $\frac{q}{P}$	Stars of Comp. B.A.C.
July 7	11 25 21·4	12 56 57·20	+8·944	26 30 6·0	−9·4211	4276
8	10 58 56·3	13 18 27·06	+8·899	27 58 53·4	−9·2692	4392
8	11 24 13·0	13 18 46·90	+8·914	28 0 29·3	−9·3821	,,
Sept. 1	10 12 11·3	15 34 31·60	+8·729	46 30 14·5	−9·6909	5287
1	10 37 8·7	15 34 32·56	+8·737	46 30 21·4	−9·7283	,,
3	8 52 44·6	15 36 47·77	+8·671	46 40 48·6	−9·5688	,,
3	9 12 43·0	15 36 48·59	+8·692	46 40 50·8	−9·6042	,,

The observations are corrected for refraction. The corrections to be applied for parallax in time and arc are represented by p and q; P is the equatoreal horizontal parallax. The following are the assumed mean places of the stars of comparison for 1861, Jan. 0.

	R.A. h m s	N.P.D. ° ′ ″	Authority.
B.A.C. 3496	10 7 53·88	24 12 1·54	Greenwich and Oxford Obs.
,, 3647	10 32 25·51	23 33 25·95	,, ,, ,,
,, 3968	11 34 41·03	22 29 9·61	British Association Catalogue.
,, 4276	12 35 28·67	26 31 24·03	,, ,, ,,
,, 4300	12 41 21·66	26 27 33·40	,, ,, ,,
,, 4392	13 0 53·52	27 12 43·14	,, ,, ,,
,, 5287	15 50 0·14	46 27 17·79	,, ,, ,,

Variations in the Light of η Argus, observed at Madras from 1853 to 1861. By Eyre B. Powell, Esq.

Mr. Powell writes that he has been engaged, off and on, during the last four years in watching the nebula about *η Argus*, and in taking micrometrical observations of the neighbouring stars; consequently his attention has been very much directed to that part of the heavens, and the estimations of the magnitude of that star have been made with very great care. The observations are as follows:—

1853·991. *η Argus* slightly inferior to *α Centauri*, but superior to either *α Crucis* or *β Centauri*.

1854·076. Inferior to *α* but superior to *β Centauri*. Rays issue from *η* as from *Rigel*.

1855·967. Not brighter than *Procyon*, and not quite so bright as *Capella*; scarcely brighter than *α Crucis*, about equal to *β Centauri*. Colour reddish or yellowish white; star scintillates.

1856·012. Scarcely brighter than *β Centauri*, a trifle brighter than *α Crucis*; scintillates more than either, and is reddish. Perhaps equals *β Centauri*, but, being reddish, strikes the eye more.

1858·367. Less than *γ Crucis*, but very little different.

1858·44. Certainly inferior to *β Crucis*, and, I think, to *γ Crucis*.

1858·479. Less than *γ Crucis*.

1858·485. Decidedly less than *ν Crucis*, but is considerably lower. A little brighter than *ι Sagittarii*, both stars having about the same altitude.

1859·274. Considerably less than *γ Crucis*.

1859·328. Much less than *γ Crucis*; a little less than *δ Argus*; a little greater than *δ Crucis*.

1859·931. About equal to *δ Centauri*; a little greater than *θ Argus*.

1859·98. Equal to *δ Centauri*; a little greater than *θ Argus*; certainly less than *γ Centauri*.

1860·165. Decidedly less than *δ Centauri*; about equal to *δ Crucis*.

1860·181. Equal to *δ Crucis* nearly, perhaps a trifle superior; both stars require attention to catch them in full moonlight.

1860·287. Equal to *δ Crucis*; not much greater than *θ Argus*.

1860·326. Equal to *δ Crucis*, the stars having about equal altitudes.

1860·972. A little less than *δ Crucis*.

1861·014. Less than *δ Crucis*; less than *θ Argus*.

1861·249. Less than *δ Crucis*; less than *θ Argus*.

1861·282. With telescope, less than the principal star in *θ Argus*.

Taking the observations in groups according to the brackets, and using Sir John Herschel's photometric magnitudes for the reference-stars, the following approximate table is obtained. Where a star of reference does not occur in Sir John Herschel's list (as is the case with *δ Crucis*, for example), ·4 has been added to the ordinary magnitude, to bring it to the photometric scale.

Epoch.	Photometric Mag.
1854·03	1·2
1855·99	1·5
1858·44	2·3
1859·3	3·1
1859·95	3·3
1860·24	3·4
1861·13	3·6

The break in the observations between 1856 and 1858 arises from my having been absent from India during that interval.

Madras, November 4th, 1861.

Results of Meridional Observations of Small Planets; Occultation of Stars by the Moon; and Phenomena of Jupiter's Satellites; observed at the Royal Observatory, Greenwich, during the month of November, 1861.

(*Communicated by the Astronomer Royal.*)

Victoria (12).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Nov. 2	12 26 22·8	3 15 23·10	69 42 26·18
7	12 1 26·9	3 10 5·87	70 22 59·01
8	11 56 27·2	3 9 1·94	70 31 13·92
11	11 41 30·4	3 5 52·33	70 56 8·14
19	11 2 1·3	2 57 49·22	72 2 22·22
20	10 57 9·1	2 56 52·76	72 10 22·27
30	10 9 31·5	2 48 32·93	73 26 7·39

Irene (14).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Nov. 2	11 36 7·1	2 24 59·11	86 47 6·18
5	11 21 31·6	2 22 10·86	86 54 23·36
11	10 52 30·1	2 16 43·98	87 5 52·52
20	10 9 42·2	2 9 18·07	87 13 59·66
27	9 37 19·5	2 4 25·97	87 12 8·12
30	9 23 44·6	2 2 38·52	87 9 1·75

Ariadne (43).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Nov. 5	9 30 0·4	0 30 21·41	81 17 5·99
7	9 21 22·0	0 29 34·71	81 27 33·29
11	9 4 28·2	0 28 24·37	81 46 22·36
19	8 32 8·9	0 27 32·20	82 14 58·30
20	8 28 15·1	0 27 34·28	82 17 27·00
27	8 1 43·9	0 28 34·64	82 30 34·84

Europa (52).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Nov. 5	9 40 50·9	0 41 13·68	95 58 39·84
7	9 32 3·7	0 40 18·14	96 0 29·62
11	9 14 53·1	0 38 50·96	96 3 46·32
20	8 37 17·0	0 36 37·71	95 59 27·43
30	7 57 30·1	0 36 9·84	95 39 58·27

All the observations of N.P.D. have been corrected for refraction and parallax.

Occultations of Stars by the Moon.

Day of Obs.	Phenomenon.	Moon's Limb.	Mean Solar Time.	Observer.
			h m s	
1861, Nov. 6	B.A.C. 6448 disapp. (*a*)	Dark	6 35 26·4	D.
17	33 Tauri, disapp. (*b*)	Bright	10 12 45·7	J. C.
17	33 Tauri, reapp. (*b*)	Dark	11 6 51·8	J. C.

(*a*) Clouds passing over the moon. (*b*) Somewhat unsatisfactory.
The initials D. and J. C., are those of Mr. Dunkin and Mr. Carpenter.

Phenomena of Jupiter's Satellites.

Day of Observation.	Satellite.	Phenomenon.	Mean Solar Time.	Observer.
1861.			h m s	
Nov. 18	IV	Occ. reapp. first cont. (*a*)	16 32 4·8	J. C.
18	IV	,, bisection (*a*)	16 45 34·2	J. C.
18	IV	,, last cont. (*a*)	16 48 33·7	J. C.
27	I	Ecl. disapp. (*b*)	14 21 49·4	D.

(*a*) The planet's image extremely bad. (*b*) The sky very hazy.
The initials as before.

Observations of Comet II., 1861, *made with the Heliometer at the Radcliffe Observatory, Oxford.* By the Rev. R. Main.

Day.	Greenwich M.T.	Apparent R.A.	Apparent N.P.D.
1861.	h m s	h m s	° ′ ″
June 30	11 1 47·4	6 40 13·07	43 25 11·1
	11 29 36·1	6 41 6·02	43 14 34·5
July 2	11 23 2·8	8 32 23·31	27 31 1·1
	11 30 4·3	8 32 45·14	27 29 42·9

Day. 1861.	Greenwich M.T. h m s	Apparent R.A. h m s	Apparent N.P.D. ° ′ ″
July 3	9 31 58·2	9 38 37·98	24 12 49·7
	9 47 43·2	9 39 24·94	24 11 24·8
4	11 5 17·8	10 51 13·03	23 5 24·7
	11 12 31·1	10 51 31·08	23 5 24·4
5	9 17 25·0	11 42 29·24	23 36 1·9
	9 22 47·1	11 42 39·82	23 36 3·6
	9 26 17·5	11 42 49·05	23 36 21·4
	9 33 42·3	11 43 1·49	....
6	9 47 58·0	12 25 1·27	24 53 0·9
	9 52 59·2	12 25 8·45	24 53 24·7
	9 57 8·9	12 25 15·06	24 53 38·7
8	10 27 22·0	13 18 1·07	27 56 35·3
	10 32 14·9	13 18 5·28	27 56 53·7
	10 38 51·7	13 18 10·79	27 57 25·3
	10 43 25·5	13 18 14·18	27 57 37·7
9	9 24 58·9	13 34 7·30	29 18 1·1
	9 33 26·5	13 34 12·91	29 18 39·3
	9 39 15·2	13 34 15·56	29 18 51·2
	10 5 31·0	13 34 30·55	29 20 20·9
10	10 22 28·1	13 47 35·60	30 38 46·1
	10 28 9·6	13 47 38·39	30 39 8·7
	10 33 14·2	13 47 40·79	30 39 25·5
	10 37 7·9	13 47 42·46	30 39 37·2
14	10 43 14·6	14 18 43·61	34 36 9·1
	10 48 39·7	14 18 45·39	34 36 24·7
	10 57 46·4	14 18 46·56	34 36 40·8
	11 6 3·9	14 18 49·10	34 36 58·6
	11 15 44·2	14 18 51·30	34 37 19·9
15	9 44 22·2	14 23 27·83	35 19 24·8
	9 54 15·1	14 23 29·59	35 19 31·6
	10 5 25·7	14 23 31·19	35 19 54·3
16	10 40 16·0	14 27 48·53	36 1 55·8
	10 45 23·2	14 27 49·36	36 2 7·8
	10 51 18·4	14 27 48·82	....
	10 57 2·5	14 27 50·92	36 2 20·0
	11 2 53·3	14 27 51·96	....
	11 8 22·6	14 27 52·87	....
	11 15 53·2	....	36 2 44·1
	11 21 22·3	....	36 2 59·5
23	10 43 26·3	14 46 (15·16)	39 27 1·4
	11 16 56·2	14 46 43·04	39 27 19·7
	11 37 21·4	14 46 44·82	39 27 19·1
	12 7 47·9	14 46 46·98	39 27 34·1

July 23. Something wrong in the first observation of R.A.

Day. 1861.	Greenwich M.T. h m s	Apparent R.A. h m s	Apparent N.P.D. ° ′ ″
July 26	10 13 5·7	14 51 50·00	40 26 14·0
Aug. 1	10 3 43·2	15 0 7·24	42 1 52·4
	10 27 56·9	15 0 7·79	42 1 55·1
	10 44 43·1	15 0 9·40	42 1 55·8
	11 11 31·6	15 0 10·00	42 2 5·3
2	9 40 17·7	15 1 27·09	42 14 43·3
	10 13 40·3	15 1 25·41	42 14 47·8
6	11 3 26·2	15 6 0·50	43 4 3·9
	11 21 32·1	15 6 0·39	43 4 21·1
	11 38 2·0	15 6 1·70	43 4 38·0
	11 53 53·0	15 6 2·55	43 5 2·9
8	11 9 44·2	15 8 14·14	43 26 16·3
	11 31 37·9	15 8 15·83	43 26 13·0
	11 47 20·9	15 8 16·60	43 26 25·4
15	10 55 9·2	15 15 45·79	44 32 44·2
	11 8 42·2	15 15 45·04	43 32 50·0
	11 22 16·8	15 15 47·56	44 32 28·4
16	8 41 9·1	15 16 45·72	44 40 1·4
	8 54 2·8	15 16 46·22	44 40 16·8
	10 6 21·4	15 16 49·40	44 40 29·2
	10 32 28·7	15 16 49·52	44 40 44·6
	10 49 21·9	15 16 50·29	44 40 29·2
19	8 43 2·5	15 19 58·65	45 3 59·6
	9 30 1·7	15 20 0·79	45 4 26·8
	9 43 22·6	15 20 0·96	45 4 29·5
	9 58 29·4	15 20 1·19	45 4 34·8
20	8 35 53·7	15 21 2·46	45 11 45·2
	8 57 18·5	15 21 3·49	45 11 58·8
	9 13 57·0	15 21 3·73	45 11 55·6
	9 48 24·4	15 21 5·75	45 12 6·1
	10 5 56·5	15 21 6·87	45 12 18·4
23	8 48 29·1	15 24 18·35	45 33 24·8
	9 23 49·1	15 24 20·49	45 33 36·9
	9 49 13·5	15 24 20·89	45 33 42·1
	10 1 45·2	15 24 21·31	45 33 44·7
	10 29 47·4	15 24 23·90	45 34 0·0
26	9 28 16·1	15 27 40·96	45 53 47·4
	9 52 15·2	15 27 41·82	45 53 47·7
	10 7 18·8	15 27 42·73	45 54 3·2
	10 16 30·0	15 27 43·56	45 54 10·0
27	8 16 20·7	15 28 43·86	45 59 48·6
	8 41 11·6	15 28 44·71	45 59 53·9
	8 55 45·7	15 28 45·73	45 59 55·9
	9 43 22·5	15 28 48·51	46 0 8·1

Day.	Greenwich M.T.	Apparent R.A.	Apparent N.P.D.
1861.	h m s	h m s	° ′ ″
Aug. 27	10 25 55·5	15 28 49·45	46 0 25·7
30	9 15 48·9	15 32 10·80	46 18 22·6
	9 50 49·0	15 32 10·25	46 17 56·3
	10 36 9·5	15 32 15·05	46 17 37·0
Sept. 3	8 15 56·4	15 36 45·81	46 40 20·8
	8 31 56·7	15 36 46·66	46 40 33·7
	9 16 45·7	15 36 49·56	46 40 42·1
	9 36 50·4	15 36 47·67	46 40 44·5
	10 1 3·9	15 36 51·25	46 40 55·3
6	8 32 12·2	15 40 20·60	46 55 41·6
	8 54 41·5	15 40 20·76	46 56 0·9
	9 5 53·6	15 40 22·74	46 55 53·8
	10 2 13·2	15 40 25·27	46 56 11·2
10	8 50 0·4	15 45 13·54	47 14 15·9
	9 10 8·7	15 45 13·66	47 14 28·0
	9 23 45·9	15 45 14·78	47 14 15·2
	9 42 52·8	15 45 15·70	47 14 26·0
12	8 32 28·1	15 47 39·65	47 22 52·6
	9 0 54·2	15 47 42·12	47 22 49·1
	9 20 50·2	15 47 43·15	47 22 49·7
	9 38 57·9	15 47 43·78	47 22 55·3
14	7 53 48·9	15 50 9·91	47 30 31·6
	8 12 44·6	15 50 9·01	47 30 18·5
	8 34 43·2	15 50 12·10	47 30 28·7
	9 13 14·7	15 50 14·21	47 30 42·5
	9 26 59·5	15 50 15·75	47 30 45·9
17	9 14 5·8	15 54 2·74	47 41 37·5

Of the preceding observations, those to July 16 inclusive were made by myself, and the remainder were made by Mr. Quirling. A wire micrometer, furnished with a single fixed transit-wire and with a declination wire moveable by the screw, was used till the faintness of the comet made it necessary to observe in a dark field over thicker wires, when a negative eye-piece with metallic cross was substituted. This change occurred on Aug. 16. But, in all cases, the declination wire was used in a fixed position, and the reading of one microscope of the hour-circle and of one microscope of the declination-circle was taken for each observation of the comet and the stars of comparison. These stars were generally taken from the Radcliffe Catalogue, and were in general so near to the comet on the night of observation that the differential effect of instrumental errors will be insignificant. On July 15 and 16 the transits of the star and comet were made with an unchanged position of the polar axis, though the circles were read as on other evenings, and the results for these evenings are

obtained by application of the index corrections obtained on other evenings.

All the observations are corrected for the effects of refraction and parallax.

The following is a list of the stars of comparison, together with the places assumed in the reduction of the observations.

Mean Places for 1861, *Jan.* 1, *of Stars compared with the Great Comet of* 1861.

Day of Comp.	Name.	Mean R.A.	Mean N.P.D.	Authority.
1861.		h m s	° ′ ″	
June 30	Capella	5 6 25·55	44 8 53·1	Nautical Almanac.
July 2	*o* Urs. Maj.	8 18 41·06	28 49 17·5	Radcliffe Catalogue.
3	*h* Urs. Maj.	9 20 31·72	26 20 0·7	,, ,,
4	*α* Urs. Maj.	10 55 7·25	27 29 58·7	Nautical Almanac.
5	,, ,,	,, ,,	,, ,,	,, ,,
,,	*γ* Urs. Maj.	11 46 30·19	35 31 57·0	,, ,,
6	76 Urs. Maj.	12 35 28·81	26 31 24·6	Radcliffe Catalogue.
8	83 Urs. Maj.	13 35 27·54	34 36 50·3	,, ,,
9	81 Urs. Maj.	13 28 46·58	33 56 17·7	,, ,,
10	84 Urs. Maj.	13 41 24·15	34 52 19·1	,, ,,
14	*	14 23 49·0	34 38 0·0	
15	*	,, ,,	,, ,,	
16	*	14 27 40·0	36 2 0·0	
,,	B.A.C. 4826	14 28 57·27	36 29 21·0	Radcliffe Catalogue.
23	B.A.C. 4937	14 51 46·18	39 48 7·4	,, ,,
26	,, ,,	,, ,,	,, ,,	,, ,,
Aug. 1	44 Boötis (2[d])	14 59 12·46	41 48 11·3	,, ,,
2	,, ,,	,, ,,	,, ,,	,, ,,
6	,, ,,	,, ,,	,, ,,	,, ,,
8	Rümker 5030	15 13 32·37	43 52 19·7	Rümker's Cat.
15	Oeltz. Arg. 15347	15 19 24·07	44 14 8·1	Oeltzen-Argel. Cat.
16	Rümker 5050	15 15 53·52	45 3 32·0	Rümker's Cat.
19	Radcliffe 3387	15 21 13·65	45 12 35·4	Radcliffe Catalogue
20	,, ,,	,, ,,	,, ,,	,, ,,
23	Radcliffe 3387	15 21 38·49	45 30 23·4	,, ,,
26	B.A.C. 5175	15 33 40·19	45 56 28·0	,, ,,
27	,, ,,	,, ,,	,, ,,	,, ,,
29	,, ,,	,, ,,	,, ,,	,, ,,
30	,, ,,	,, ,,	,, ,,	,, ,,
Sept. 3	,, ,,	,, ,,	,, ,,	,, ,,
6	Radcliffe 3448	15 41 28·95	47 5 56·0	,, ,,
10	*ψ* Herculis	15 47 52·16	47 9 27·7	,, ,,
12	,, ,,	,, ,,	,, ,,	,, ,,
14	4 Herculis	15 50 50·05	47 1 39·65	,, ,,
17	,, ,,	,, ,,	,, ,,	,, ,,

On June 30 the comet was also observed on the meridian with the transit-instrument and the meridian-circle, and the following is the result of the observation:—

1861, June 30	$12^h\ 11^m\ 5^s{\cdot}9$	Greenwich Mean Solar Time.
	Apparent R.A.	$6^h\ 42^m\ 10^s{\cdot}89$
	Apparent N.P.D.	$42^\circ\ 56'\ 56''{\cdot}1$

the N.P.D. being corrected for refraction and parallax.

The following are the notes which I made on the appearance of the comet:—

1861, June 30. This splendid comet burst suddenly on the view this evening. I saw it first at about 10 o'clock, and immediately prepared to observe it. Its appearance, notwithstanding the strong daylight, was most brilliant. To the naked eye the condensation of light about the head was so great as to bear comparison with the Moon rather than with any other object. In fact the diameter of the coma was about 30′ by measurement at some Observatories on this evening. The tail streamed vertically upwards, and near midnight could be traced considerably beyond *Polaris,* which it passed over. Its length on this evening has been variously estimated from 100° to 120° by the most careful observers.

In the telescope of the heliometer there appeared a nucleus of an elliptical shape, with its major axis a little inclined to the vertical, that is, directed nearly towards the Sun. It was about the size of the ball of *Saturn,* near opposition, or about 20″ in diameter. A stream of light went off from the upper apparent part of the nucleus, and turned round towards the apparent west in the shape of a sickle. Another but fainter stream was seen on the apparent east side of the first stream, also turning round towards the west.

July 2. In appearance not very different from that on June 30. A sickle-shaped stream of light setting out westward (apparently), and seeming for a little distance parallel to the declination wire, and then turning rapidly downwards (that is, away from the Sun). The nucleus elliptical as before, with its major axis inclined at an angle of 15° to the declination wire. The second stream of light was visible, but not so well defined as before. Clouds rendered physical observations difficult. The tail at least 70° in length.

July 3. The evening was too cloudy for accurate physical observations, but it appeared as if the formations round the nucleus were becoming more regular and concentric, and more like Donati's comet. At midnight the clouds cleared away, and the view of the comet with the naked eye was magnificent. The tail was about 60° in length, being visible beyond the zenith.

July 4. The comet is rapidly becoming fainter. The tail could not be traced farther than 40° from the nucleus, but the brilliancy of the nucleus is still very great. In the telescope the nucleus appeared pear-shaped, with the point (apparently westward) and the axis parallel to the declination axis. Two curved streams of light are still seen flowing from it, the lower one sickle-shaped, but not so well defined as previously, cutting the declination wire at an angle of about 60°; the upper arc ill defined and cutting the declination wire at an angle of 30°. The whole formed the sector of a circle of about 100°.

July 5. I examined the head of the comet to-night with a lower power. The nucleus is now very bright, and almost equal to a star of the first magnitude (I compared with α *Ursæ Majoris* in the twilight). It is of the same shape as on the preceding night. The head of the comet is altogether like a fan expanded to about 120°. Round the nucleus is a very bright circle of light, scarcely separable from it, and the two diverging streams of light now pass symmetrically on each side of the nucleus.

July 9. The shape of the head is that of an expanded fan. The nucleus terminates in a bright stellar point towards the apparent east, and is very narrow and pear-shaped, running parallel to the declination wire (or to the equator). Round the nucleus is a bright envelope of a circular shape, and, beyond that, another very faint and diffused. The distinctness of the envelope is not at all comparable with Donati's comet of 1858. The whole of the field is very strongly illuminated with the light of the comet.

July 10. The appearance of the comet has not materially changed since last night, except that the shape of the nucleus is materially different, having become more obtuse.

By my directions, Mr. Quirling confined himself for several evenings after the first appearance of the comet to observations of the length, breadth, and peculiarities of the tail, and incorporated the results of his observations in a series of drawings, in which the position and magnitude of the tail are defined accurately by means of the stars which it passed over or near to. The following is an abstract of his observations:—

"July 4. This was the first favourable evening after June 30 for observations of the tail. At $10^h 40^m$ the head of the comet was nearly in a line with α and β *Ursæ Majoris*, and the northern boundary of the tail passed just over α *Draconis*, and could be traced a short distance beyond that star. The estimated length was about 25°. The shape near the head was that of a very flat parabola, and the northern boundary was by far the brighter one.

"At $11^h 30^m$, the darkness being greater, the comet had increased considerably in apparent brightness. The northern border of the tail passed beyond α and ι *Draconis*, which were seen through it; it passed exactly over ι *Draconis*, and could

be traced towards τ *Herculis.* The southern border was far less distinct; it passed north of ϑ *Draconis*, of several stars of the 6th magnitude. Estimated length, about 44°.

"At 12^h, the northern border could be traced beyond η *Herculis;* the southern border still less distinct than the northern. In the vicinity of δ *Draconis* there seemed to be faint traces of a second tail. Whole length of tail, 60° to 65°; breadth, 7° to 8°.

"July 5, $11^h 30^m$. Sky very fine. The tail could be traced nearly to τ *Herculis*, the northern boundary being still the better defined. The southern border scarcely reached δ *Draconis*, and passed over ι and κ *Böotis*, where there was again the faint beginning of a second tail, bending northwards, as on the night before. The tail did not reach τ *Herculis.* Length, about 45°; greatest breadth, 10°.

"July 8, $11^h 30^m$. The evening in general not favourable. The comet considerably fainter than on July 5, but still a conspicuous object in the heavens. The centre of the tail pointed midway between ρ and χ *Herculis;* but it could not be traced up to those stars. The fan or second tail, which was observed on July 4 and 5, had entirely disappeared. Length, about 27°.

"July 9. General appearance nearly the same as on the preceding night. Length, about 20° to 24°.

"July 14. The comet considerably smaller. The head, which had been up to this time always estimated as of the 1st and 2d magnitude, was to-night decidedly not brighter than a star of the 3d magnitude. Both borders of the tail well defined, though the northern could be traced farther than the southern. Length of tail, 15° or 16°.

"July 16. The appearance very similar to that on July 14. Length, 12° or 13°."

Progress of the Charts in course of execution at Bonn. Communicated by Mr. Carrington, as received from Dr. Krüger, by the direction of Dr. Argelander.

Seven sections, each comprising four sheets, are published. The first four sections were received several months since by the Observatories and Astronomers to whom they are presented. Sections 5, 6, and 7 were despatched, through Marcus of Bonn, at the end of last October; and vols. iii. and iv. of the *Bonn Observations*, being vols. i. and ii. of the present *Survey*, are about to follow. The charts comprising the Zone 2° S. to 20° N., and the next, 20° N. to 40° N., are fully published; and section 7, containing sheets 26, 27, 32, 33, will amount to half the next Zone, 40° to 60° N.

The observations by zones of 2 and 3 degrees broad with the 34-lines telescope were brought to a close at 81° N. on March 27, 1859, and amount to 1841 zones. By means of auxiliary tables, the positions of all the stars of Bessel's zones, from +15° to +45° from Weisse's catalogue, Oeltzen's catalogue, &c. were brought up to 1855·0, and entered in the same ledgers (about 190 in number), which record the original entries of times of transit in the Bonn zones. In order to see by inspection that each star was twice observed, a special catalogue was transcribed, in which the positions were arranged in zones of one hour each, and one degree broad. When the two observations of each star had been thus compared, the next step was the reduction to 1855 of all the stars contained in the former Catalogues of Lalande, Bessel, Argelander, Piazzi, Groombridge, Johnson, Rümker, Fedorenko, Schwerd, Struve (*Pos. Med.*), &c.; and the entering of the results alongside of those of the *Bonn Survey;* when, if the different authorities exhibited marked discrepancies, a further research was instituted. All cases of discrepancy were put aside, and entered in books for further examination or reobservation where the source of error was not easily detected.

The re-examination of the still dubious cases has been, for the most part, the special labour of Dr. Argelander himself, and a very laborious and important part of the undertaking, the necessary observations on the meridian having engaged his whole time from 1854 to 1860.

It has further been found necessary to repeat the survey in portions of the heavens unusually rich in stars, or where the previous ordinary survey had been taken during moonshine. For this purpose 476 additional Revision-Zones have been observed with a 5-foot telescope, by taking 1° only at a time in breadth, and on an average a much less extent in right ascension than those of the first survey.

In addition to the revision of doubtful stars, Professor Argelander has completely observed all stars to the 8th magnitude the positions whereof were found to be previously undetermined. The results of these observations will be embodied in a separate catalogue of about 30,000 stars observed with the meridian circle. The revision-observations of this class have been long in progress, so that the number of still undetermined stars is reduced to about 1000, and the whole is likely to be finished next summer. The reduction of these observations is somewhat in arrear, and a year or more may be required before the catalogue can be formed.

Dr. Krüger proceeds to remark, that after the correction of all known errors, the next step was the preparation of the principal catalogue, the arrangement of which he describes, but which can be seen by inspection of the work itself. He points out that the fourth volume contains a catalogue of all the errors detected at Bonn in the zones of Bessel, from −2°

to $+45^\circ$ decl., and states that the result of the revision appears to be, that, excepting two cases of observations of planets, the whole of the observations of Bessel agree with positions of stars which still exist. He remarks that the result affords a weighty argument against those who hastily speak of vanished stars, and that the stability of the heavens has received so strong a support that suppositions of sudden change will in future be received with the greatest mistrust.

The preparation of the principal catalogue was assigned to Prof. Schonfeld, who has continued to forward the work since his removal to Mannheim; so that now the manuscript is complete.

The preceding account relates to north declination to 81°. It was considered impossible to continue the observations in zones beyond this point, on account of the extremely slow movement of the stars, and recourse was had to the first issue of Mr. Carrington's Charts (those printed by the anastatic process), which were compared anew with the heavens by means of a large comet-seeker, the magnitudes noted, and wanting stars supplied—the last by use of the heliometer.

To complete this work there now remains only the plotting out of certain charts, and the printing by lithography; and only three sheets besides the polar chart are incomplete. The rest are partly finished, partly in the press, and partly in MSS.

The catalogue progresses simultaneously, and the third section is in the press. When this is done, there will follow the special catalogue of 30,000 stars observed on the meridian, and the correction of errors in the Histoire Celeste, Argelander's Northern Zones, and other catalogues.

The Fellows of the Society, and all to whom this account comes, cannot fail to admire the stately progress of this enormous work, which, simple in its conception, and free from insurmountable difficulties in execution, would appal many an astronomer by its vast extent.

The President communicated a letter from Mr. Basil Henry Cooper, "On the Egyptian Phœnix Period of 540 years, spoken of in a passage of Pliny." The letter partly relates to an eclipse of the Moon, recorded in a hieroglyphical inscription at Karnak, which the author concludes to have been that of the night of the 16 March, B.C. 851.

The President communicated observations by Mr. S. Hort of Encke's Comet, and of the planet *Saturn*, extracted fro the Hartwell Observatory Register. The comet was seen:—

	1861, Nov. 24.	Nov. 26.	Nov. 30.
Right Ascension	$22^h\ 31^m$	$22^h\ 29^m$	$22^h\ 25^m$
Declination	$7^\circ\ 53'$	$7^\circ\ 29'$	$6^\circ\ 49'$
Hour Angle	$2^h\ 13^m$	4^h	2^h
Clock	$0^h\ 45^m$	$2^h\ 31^m$	$0^h\ 26^m$

Power 22 and 50.

Among the presents to the Society was included a volume of 111 Indian-ink drawings, by Mr. S. Gorton, of the planet *Jupiter*, radius about one inch, from observations made at Downs Road, Clapton, in the years 1859–60–61. The author remarks that as the observations were taken for the purpose of recording any great or marked changes in the principal belts, with an instrument of moderate size, the representation of those minute details for which great power was necessary was not attempted. The earlier drawings were made under some disadvantages—the telescope being used at a window, and not having an equatoreal mounting; this was added in April 1860, after which the planet was observed more regularly.

The power used was almost invariably 100; the telescope by Ross, 4 feet focal length, $3\frac{7}{8}$ inches aperture.

An Account of Observations on Solar Radiation.
By John James Waterston, Esq.

§ 1. In March of last year I submitted to the Society some computations with reference to the Sun's heat, and suggesting a mode of deducing the potential temperature of its radiating surface. This last summer I have endeavoured to put this method to the proof by a series of observations on solar radiation, supplemented with experiments on the rate of cooling of thermometers in air and in vacuo with different kinds of radiating surfaces; also by another series applying the method of deducing the potential temperature of a radiating surface to predicate the temperature of one that is maintained at a constant *known* temperature.

The success of these last mentioned, so far as they have as yet been carried, encourages me to lay before the Society the observations on solar radiation, with an account of the method

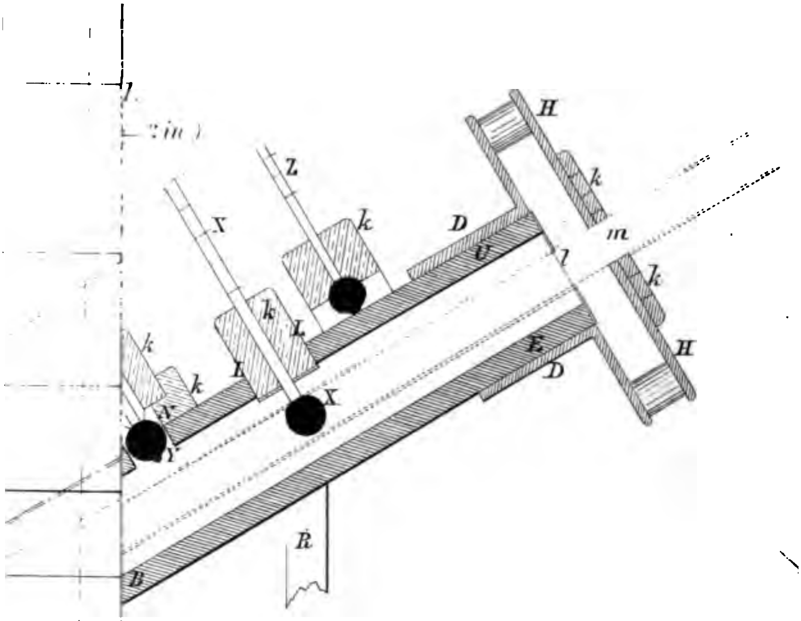
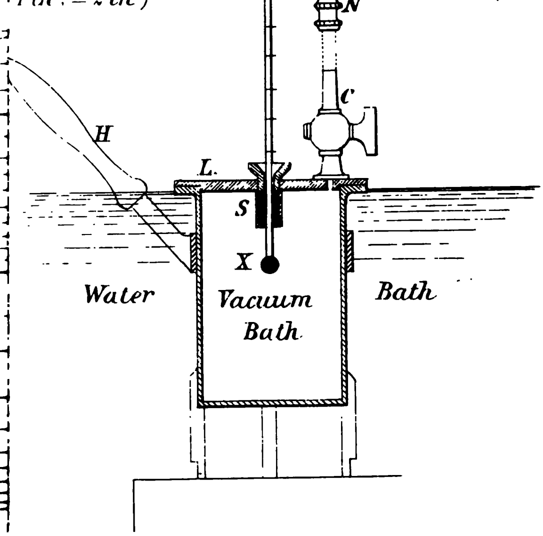


Fig. 2.
(1 in := 2 in)



employed to obtain the results, and of the mode of reducing them to a vacuum.

§ 2. It will be remarked, on inspecting the chart in which the observations are projected, that a simple law of atmospheric absorption is indicated, which, if confirmed by other similar observations in different climates, would perhaps lead to more exact ideas of the influence of the atmosphere on the Sun's rays. Unfortunately the best part of the summer had passed before I could begin to observe, and there was almost constant interruption with clouds and unsettled weather. In a tropical station, where the Sun rules in a cloudless sky, the presumed law might soon be put to the test, and the heating power of the Sun's rays before entering the atmosphere ascertained with precision. Having determined this for the Earth's mean distance from the Sun, its value for any other planetary distance may be deduced by the law of the inverse square.

§ 3. When a thermometer is exposed to the Sun with its bulb blackened, it is presumed to absorb all the heat that impinges on a plane surface equal to the transverse section of the bulb; it rises and is maintained at a certain temperature; and when this balanced condition is attained we can with certainty assert that the amount that issues from the bulb is precisely equal to the quantity that enters. The elevation of its temperature above surrounding bodies due to the Sun's radiant power (which is denoted by the symbol r) would be an exact measure of that power, if no heat issued from it except by radiation, and if the rate at which heat was emitted from it increased exactly in proportion to r. Now I find that if the bulb of a thermometer is enclosed in a vacuum, the walls of which are brass, coated with lamp-black, the rate at which it cools is *exactly* proportional to the value of r, and this rate has exactly the same value, whether the glass bulb is uncoated or coated with lamp-black. When enclosed in air the rate of cooling increases faster than r. The mode of measuring the rate in both cases, and of reducing the values of r observed in air to what they would be in a vacuum, are described at the end of this paper.

§ 4. The instrument employed was designed so that the thermometer exposed to the Sun's rays should radiate against an enclosing metallic surface coated with lamp-black, and so that the temperature of that surface should always be known.

Fig. 1, with the description that accompanies it, gives the details. The rays of the Sun were admitted to strike upon the bulb of the thermometer, X, through a hole but little larger than its diameter, and were entirely screened off the brass tube against the blackened inner surface of which the radiation of the bulb took place. The thickness of the sides of the brass tube was $\frac{1}{4}$ inch, and the thermometer, Y, that indicated its temperature, was lodged in a hole cut in the upper side. The circumference of the bulb touched the brass, and its upper side

was enclosed with cork, while the lower was exposed to the air within the tube, but was untouched by the rays of the Sun that passed through. The internal diameter of the tube was 0·9 inch and length 6 inches. The bulb of the solar thermometer was 0·42 inch in diameter, spherical in shape, and fixed in the centre, as shown in the figure. Its shadow was an easy guide in moving the tube in altitude and azimuth to keep pace with the Sun. It is difficult, if not impossible, to demonstrate that the thermometer, Y, shows the exact temperature of the inner surface of the tube. It was subjected to three tests.

1. The instrument being out of the Sun's rays, and X and Y showing the same temperature, it was removed to a place where the atmospheric temperature was 10° lower. Both thermometers descended and showed a difference equal to about one-tenth the amount they had to fall to arrive at the atmospheric temperature, Y being so much in advance of X.

2. A bat's-wing flame of gas was brought within 3 inches fronting the middle of the tube; both X and Y rose together, keeping pace exactly.

3. While taking observations, the heat absorbed by X from the Sun, and again emitted from it and transferred to the tube, gradually raised its temperature until a maximum was obtained. Now, comparing X and Y while both are rising, and after having obtained their maximum, a difference of 0°·3 was remarked, and this difference, no doubt, affected isolated observations when this maximum was not attained, in consequence of interruption by clouds passing, when it was usual to heat the solar thermometer artificially to near the stationary point, in order to save time; the great inconvenience of the apparatus in this climate being the slowness with which r obtained its final value. An arrangement with a differential air-thermometer would, no doubt, be preferable in this respect, but the absolute value of the degrees indicated does not seem capable of being exactly determined.

The thermometers were carefully graduated and compared by myself, and the divisions between two fixed points, 60° and 100° (which included all the observed temperatures), were drawn as nearly equal as a good ivory scale and magnifying lens would admit. The length of a degree on the scale of Y was about ·05 inch, and upon X ·067 inch; with practised eye it was easy to read off the temperature to $\frac{1}{20}$th of a degree with lens; but such accuracy was unattainable for other reasons, and chiefly a sensible difference was caused by the varying amount of the stem that was under the influence of the Sun's rays as it moved.

The observations taken on the morning of the 21st August continuously, during $2\frac{1}{2}$ hours of uninterrupted sunshine, were graphically equalised, the curve drawn and ordinates measured off at every 20 minutes. This was the only opportunity that occurred of continuous observation between such favourable

limits of altitude as to indicate the direction of a line with some precision.

In the table of observations, given in the Appendix, the date and apparent time are given in the first column. The time-piece was regulated daily by the one o'clock signal-gun. The second column contains the values of r, the observed difference between thermometers X and Y. The film of talc that was interposed between the Sun and X was found to reflect $\frac{9}{50}$th of the incident rays. This ratio was determined by observations taken with the film off during calm weather. The value of r without the film to r with the film on, was as 1·18 to 1·00; the sun's power not sensibly varying during the interval. This proportion was maintained at low values of r, and even when the source of radiation was a gas-flame. The third column contains the observed values of r increased in this ratio. The fourth column contains the corrections required to reduce the values in the third to a vacuum. The correction is taken from a scale that was constructed by means of an empirical formula derived from observations on the cooling of X, as detailed in the Appendix. The fifth column is the final value of r as it would appear in a naked vacuum, that is, a vacuum without any interposed transparent solid between the Sun and the bulb of the thermometer. The numbers in this column represent the quantity of heat-force supplied from the Sun to the bulb of the thermometer in a constant element of time, or the quantity that emanates from the bulb in a unit of time.

The experiments on the cooling of the thermometer, X, in a vacuum, show that from $r = 30°$ to $r = 15°$, the time of cooling was 294 beats of a time-piece, of which $77\frac{1}{2}$ were equal to 60 seconds; also from $r = 15°$ to $r = 7\frac{1}{2}°$, the time was the same, and generally from $r = 2\,m$ to $r = m$ the elapsed time is the constant 294, which thus represents the logarithm of 2 in the logarithmic curve, of which the ordinates are r and the abscissæ the time of cooling, t. The equation of the curve being $c \log \frac{r_1}{r_0} = t_1 - t_0$, in which $c \log 2 = 294$, or to reduce to seconds, $c \log 2 = 294 \times \frac{60}{77\frac{1}{2}}$, and $c = 756{\cdot}1$. Let $t_1 - t_0 = \delta t$, then $\log \frac{r_1}{r_0} = \frac{1}{\mu} \cdot \frac{\delta r}{r}$, in which $\mu =$ hyp. log of 10; hence

$$\frac{c}{\mu} \cdot \frac{\delta r}{r} = \delta t \qquad \left[\log \frac{c}{\mu} = 2{\cdot}51636\right].$$

From this we may compute the quantity of heat supplied to a unit of surface by the Sun in a unit of time corresponding to any value of r. As an example, suppose $r = 10°$ and $\delta t = 1$ second, then $\delta r = \frac{10\mu}{c} = 0°{\cdot}030453$, or $3°{\cdot}0453$ in 100 seconds, is the rate at which the Sun communicates heat to a thermometer, whose bulb is a sphere 0·42 inch in diameter, when $r = 10°$.

Suppose the glass of the bulb to be $\frac{1}{50}$th of an inch thick, there would be ·0108 cubic inch glass and ·0287 cubic inch mercury heated 3°·045 in 100 seconds. If $r = 20^{\circ}$, the same heating would take place in 50 seconds, and so on.

To reduce this to thickness of ice melted in 1 minute, we have

Specific heat of mercury ·033 and of glass ·177.

Specific gravity of mercury 13·5 and of glass 2·9.

·0108 cubic inch glass equal in weight to ·0313 cubic inch water.

·0287 cubic inch mercury equal in weight to ·387 cubic inch water.

·0108 cubic inch glass raised 3°·045 takes as much heat as ·0313 cubic inch water raised 0°·54.

·0287 cubic inch mercury raised 3°·045 takes as much heat as ·387 cubic inch water raised 0°·101.

·0313 cubic inch water raised 0°·54 takes as much heat as is required to raise 1 cubic inch 0°·0169.

·387 cubic inch water raised 0°·101 takes as much heat as is required to raise 1 cubic inch 0°·0391.

The entire bulb of the thermometer thus raised 3°·045 is thus equal to 1 cub. in. of water raised ·0169 + ·0391 = 0°·056.

Now, the transverse section of bulb is 0·138 square inch; and since specific gravity of ice is 0·93, and it requires 140° to melt ice, we have $140 \times 0{\cdot}738 \times 0{\cdot}93 \times x = 3{\cdot}045$; hence $x = 0{\cdot}00312$ inch, the thickness of ice melted by the Sun in 100 seconds, when $r = 10^{\circ}$. This is equivalent to 0·001872 inch in 1 minute. With $r = 20^{\circ}$ the thickness would be double this amount, and so on. Thus the presumed extra atmospheric value of r being 67° gives 0·0124 inch thickness melted per minute.

From June to December the amount may be expected to vary $\frac{1}{15}$th, corresponding to alteration of Sun's distance. In Herschel's *Meteorology* the probable thickness is stated to be ·0109 inch.

If the law indicated by straight lines on the chart is true it would require extremely accurate observations to give the extra atmospheric constant of solar radiation with precision. From a single observation made in Bombay some years ago I am disposed to believe it may exceed 67° considerably.

The mode of approaching the law of absorption is as follows:—Project the values of r as ordinates to the secants of zenith distances as abscissæ. The resulting curve is evidently hyperbolic in character. If it is the conic hyperbola, the reciprocals of the ordinates laid off to the same abscissæ should range in a straight line. The obvious plan is, therefore, to lay off the reciprocals of r in this way, and see how far their range agrees with the straight, and, if it differs, the character of the

divergence might lead us to the true function that expresses the natural law, if it was not very complicated, and if the condition of the atmosphere did not vary so rapidly as to obscure it.

The observations, though taken under unfavourable conditions, favour the simple hyperbola.

It will be remarked, on inspecting the chart, that the value of r at the same altitude of the Sun diminishes with the declination as the season advances. If continuous observations were possible for a few hours each day, when the altitude of the sun ranged between 15° and 45°, we might expect to see the projection of the equalised observations range each day in a different line; but these lines ought all to converge on nearly the same point in the ordinate at the zero of the secant scale, if the law holds good. The lines A C, A D, A E, will exemplify this.

Let N, fig. 3, be the position of the observer, Z his zenith, and NS the direction of the sun. Draw parallel lines $a\,b$, $c\,d$, &c.; now $a\,c : b\,d$ :: rad.: sec. sun's zenith distance, so that the thickness of each stratum varies as the secant; and if the physical condition of the stratum did not alter between two observations, we may take the secant as the representative of the collective thickness of the absorbing medium traversed by the Sun's rays, except at such low altitudes when the curvature of the earth as well as refraction may be expected to introduce uncertainty. The minimum value of the secant is radius, but we may imagine the Sun's rays to pass through a similarly constituted atmosphere in which the thickness of the same layers proportionally diminishes from unity or radius to zero. The reciprocal of r diminished for values below radius at the same rate as for values above radius, attains at zero the extra atmospheric limit which, in all climates and seasons, ought to be determined by the inverse square of our planet's distance from the Sun in its orbit, and should not vary beyond $\frac{1}{30}$th of its mean value.

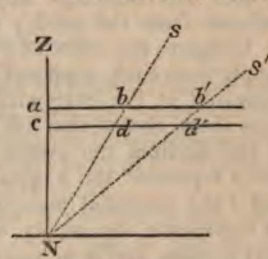


Fig. 3.

Le m_0, m_1, be the secants at which the radiation is r_0, r_1, we have, according to the projection $\dfrac{m_0 - m_1}{\frac{1}{r_0} - \frac{1}{r_1}} = k$, a constant quantity, so long as the physical condition of the atmosphere remains constant; and to find R, the extra atmospheric value of r, we have

$$m_0 - m_1 : \frac{1}{r_0} - \frac{1}{r_1} :: m_1 : \frac{1}{r_1} - \frac{1}{R}.$$

Hence $m = \frac{k}{r} - \frac{k}{R}$ and $\frac{1}{R} = \frac{1}{r} - \frac{m}{k}$. Since R is constant, we may put $\frac{k}{R} = e$, so that $r = \frac{k}{m+e}$. This expresses the presumed law of absorption or interception.

The essential nature of this law is seen by studying the proportionate differential of r,

$$-\delta r = \frac{k\,\delta m}{(m+e)^2} \text{ and } \frac{-\delta r}{r} = \frac{\delta m}{m+e} = \delta m\,\frac{r}{k}; \text{ hence } \frac{-\delta r}{\delta m} \propto r^2.$$

Thus the Sun's rays, in passing through a constant element of the thickness of the atmospheric medium, loses a proportionate amount of its power that is not constant, but that diminishes in the simple ratio of that power.

As an example, suppose with $r = 30°$, the value diminishes $1°$ in passing through 1 mile, it would only lose $\frac{1}{4}°$ in passing through the same mile if $r = 15°$, and $\frac{1}{900}$th of a degree if $r = 1°$. We might thus expect, when the atmosphere is clear, it does not intercept any sensible proportion of the heat radiated from the earth's surface into space.

Compare the value of r with one Sun and with two; the supply from each, supposed equal, doubles the value of r, which, measured at the extremities of the mile nearest and furthest from them, shows that for the same element of the thickness of the medium the proportionate decrement of r is constant. Let α represent the angular space occupied by the Sun's disk, and t the potential temperature of its radiating surface, then $t\,\alpha$ represents the supply of heat by radiation from it upon a unit surface, and is measured by r, so that if $\alpha\,t$ becomes $2\,\alpha\,t$, r becomes $2\,r$. Now, the factor 2 may have reference to α, the magnitude of the Sun's disk, or it may have reference to t, its temperature. The fluctuating value of r from change of altitude or climate represents a fluctuating potential value of $\alpha\,t$, but α being constant, the change is similar to what would take place above the atmosphere by a change in t alone. At different parts of the earth's orbit the value of α changes, so that with t constant and α variable the proportionate absorption represented by $\frac{\delta r}{r\,\delta m}$ is a constant quantity, but so far as r depends on t the value $\frac{\delta r}{r\,\delta m}$ increases with t, and the causal relation may be expressed as follows:—

The heat-pulse travels, carrying with it an intensity that it borrows from the temperature of its source, and encounters a deflecting or absorbing power in passing through a constant element of the atmospheric medium that is exactly proportional to that intensity.

It would be simpler if the resistance was uniform,—if the proportion of force absorbed was constant; but the observations do not admit of the possibility of this. The curve traced out

by the co-ordinates, r and secant zenith distance, would in that case be no longer the conic hyperbola, but the logarithmic curve.

At 6 o'clock in the evening of the 31st July, while making an observation, an extensive shower of thin rain took place overhead and westward towards the Sun, without sensibly obscuring its light or affecting its image when examined through a telescope. The value of r descended immediately from $15°$ to $13°$. The single observation I took in India, compared with those taken at the same altitude in this country, indicates that the value of r is there fully double what it is here, while the quantity of vapour held in suspension estimated from the dew-point is certainly greater. It would seem probable, therefore, that the absorbing power of the atmosphere depends on the watery particles contained in it, not upon the aqueous vapour dissolved in it.

[The Appendix, received simultaneously with the foregoing, will appear in the following number of the *Notices.*—Ed.]

26 *Royal Crescent, Edinburgh, Nov.* 25, 1861.

Explanation of the figures.

Fig. 1. T, U, B, E, is a square tube of brass, mounted with motion in altitude upon an upright, R, fixed into a round slab of lead. The inner surface of this tube is blackened, and at each end, at l and c, a film of transparent talc was stuck on to prevent the wind from moving the air within the tube.

H, D, D, H, a double screen made of cardboard and cork, coated on both sides with tin-foil, and fitted to slip on the extremity of the tube presented towards the sun.

m, the hole in centre of screen, about $\frac{1}{10}$th inch greater diameter than the bulb of the solar thermometer, X.

The talc film, l, was also coated with tin-foil except the central circle.

X, the thermometer in sun with spherical bulb fixed in a cork that fitted the hole, L, L, in top of brass tube.

Y, the thermometer in the shade fixed in the hole, N, N, with cork and soft wax as shown.

Z, a thermometer applied to outer surface of tube.

Fig. 2 is a transverse section of vacuum bath, employed to ascertain the rate of cooling of the solar thermometer, X, in air and in vacuo.

It consists of a cylindrical vessel of brass, coated internally with lamp-black; the lid, L, is ground to the upper edge of the cylinder, and in its centre is a stuffing box, S, with Indian-rubber collar, through which the stem of the thermometer is passed, as shown in the figure; C, is a stop-cock, upon which, N, the nozzle of a flexible tube communicating with an air-pump, is ground air-tight. H is a wooden handle for removing the apparatus to and from the bath without touching the metal.

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Printed by Strangeways and Walden, Castle St. Leicester Sq., and Published at the Apartments of the Society, January 9, 1862.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXII. *Jan.* 10, 1862. No. 3.

Dr. LEE, President, in the Chair.

The Rev. Thomas Pyne, Hook, near Kingston-on-Thames;
James McDowell, Esq., Perse Grammar School, Cambridge;
William Wray, Esq., 25 Torriano Terrace, Kentish Town;
C. H. Lake, Esq., Oxford House, King's Road, Chelsea;
Signor Julian Vertu, Lincoln;
John Kidd, Esq., Sherborne, Dorset; and
James Breen, Esq.,

were balloted for and duly elected Fellows of the Society.

An Account of Experiments on Solar Radiation.—Appendix describing the Method employed to discover the Influence of the Air in the Cooling of the Sun Thermometer X., and of Ascertaining the Correction required to be Applied to Observations of r, so as to reduce them to a Vacuum. By John James Waterston, Esq.

Fig. 2* is an upright section of the little apparatus or vacuum-bath. It consists of a cylindrical vessel of brass

* See last number of the *Notices:* the scale is 1 in. = 4 in.—ED.

coated internally with lamp-black. The lid was ground air-tight to the upper edge, and had a stuffing-box in the centre, through which the stem of the thermometer was passed. A stop-cock enabled a communication to be made with an air-pump. With a plentiful supply of lard to the stuffing-box and ground surfaces, a good vacuum could be maintained for a day unimpaired.

The time was measured by the beats of a clock: to register the number of these at each degree as the mercury of the thermometer descended, a scale of equal parts was prepared extending to 1000, and with distinguishing marks at each 5, 10, 50, and 100. Then with a pencil in the right hand over the scale and a magnifying glass in the left over the scale of the thermometer, I counted the beats, and when the mercury came to the line of a degree, made a mark on the scale of equal parts opposite the number of beats, and at the same time continued to count on; *e. g.* if 57 was the number when the mercury came to a line, a pencil-mark was made at 57 on the scale of equal parts, and the counting went on,—58, 59, &c. until the mercury came to the next line.

Thus, not a beat was lost from beginning to end, and the accuracy was only limited by the accuracy of the divisions on the scale of the thermometer. Indeed, this method is a severe test to the equality of the divisions, because the reciprocal of the differences in the number of the beats for each degree, if laid off as ordinates to the total number of beats, ought to range in a straight line, and any saw-like irregularities indicate inaccuracy in the divisions of the scale of the thermometer. To heat the bulb of the thermometer a funnel was placed over the small flame of a Bunsen; then holding the plate (having the thermometer fixed in its place) by means of the stop-cock, the bulb was brought over the top of the funnel until the mercury had risen to near the top of the scale. The plate was then quickly placed on the cylinder, communication made with the air-pump, and the air exhausted from the cylinder by 20 strokes, the capacity of the pump being about one-third that of the cylindrical vessel or vacuum-bath. The vessel thus exhausted was placed in a water-bath, the temperature of which was ascertained at the beginning and end; the difference seldom amounting to $\frac{1}{10}$th of a degree.

The following table exhibits two series of observations on the cooling of the sun thermometer, x, in the vacuum, and in air taken while the water-bath remained steady at 48°. This basal temperature being at an exact degree enables the rate of cooling to be studied easily without fractional parts or interpolation :—

Temp. X.	Beats in Vacuum.	r.	Beats in Air.	Temp. X.	Beats in Vacuum.	r.	Beats in Air.
90°		42°	0	90°		42°	
85°	0	37°	36	65°	323	17°	270
4	12	36		4	348	16	291
3	24	35		3	377	15	312
2	36	34		2	406	14	336
1	48	33		1	437	13	360
80	60½	32	78	60	470	12	385
9	73	31		9	510	11	414
8	86	30		8	549	10	448
7	100½	29		7	594	9	484
6	115	28		6	643	8	527
75	130½	27	129	55	704	7	576
4	145½	26		4	765	6	630
3	161	25		3	843	5	695
2	179½	24		2	...	4	780
1	197	23		1	...	3	
70	214	22	191	50	...	2	
9	235	21		9	...	1	
8	255	20		48	...	0	
7	276	19					
6	298	18					

Thus, 53, being the last observation of the vacuum cooling, corresponds with $r = 5°$; then

At $r = 5$	we have 843 beats	Difference 294	
$r = 10$	,, 549 ,,	,, 294	Mean Difference 291·7
$r = 20$	,, 255 ,,	,, 287	
$r = 40$	,, −32 ,,		

Again, beginning with $r = 7°$,

At $r = 7$	we have 704 beats	Difference 298	
$r = 14$	,, 406 ,,	,, 291	Mean Difference 294½
$r = 28$	,, 115 ,,		

And beginning with $r = 9$,

At $r = 9$	we have 594 beats	Difference 296	
$r = 18$	,, 298 ,,	,, 286	Mean Difference 291
$r = 36$	,, 12 ,,		

The numbers in the column of differences ought to be the same if the law of cooling in a vacuum is perfectly true, if the vacuum is complete, and if the graduation of the thermometer is correct. The difference between them is so small that the result must, I think, be deemed satisfactory.

Let us study the same differences with the cooling in air:—

At $r = 5°$	we have 695 beats		
		1st Difference 247	
$r = 10$	" 448 "		2d Difference 19
		" 228	
$r = 20$	" 220 "		" 22
		" 206	
$r = 40$	" 14 "		

$r = 7°$	we have 576 beats		
		1st Difference 240	
$r = 14$	" 336 "		2d Difference 23
		" 217	
$r = 28$	" 119 "		

$r = 9°$	we have 484 beats		
		1st Difference 230	
$r = 18$	" 254 "		2d Difference 20
		" 210	
$r = 36$	" 44 "		

Thus, it appears that in air the cooling takes place in a ratio greater than r, the 1st difference of the times diminishing and the 2d difference slightly increasing between 247 and 210. The limiting value of the 1st difference must be 294 when $r = 0$, and 294 minus the 1st difference increases nearly as $\sqrt{r}$. An empirical formula constructed in conformity with this ratio cannot differ much from the observations.

Let Δ represent 1st difference and g a constant,

$$\Delta = 294 - g\sqrt{r} \quad \text{and} \quad g = \frac{294 - 247}{\sqrt{7\frac{1}{2}}} = 17{\cdot}162 = \frac{294 - 210}{\sqrt{27}} = \text{\&c. (nearly)}.$$

Δ represents the logarithm of 2, so that c being a constant, we have $\log r = \frac{\Delta}{c}$. In the curve that represents the cooling in air we may assume a small arc of it to coincide with a true logarithmic curve or the curve of cooling in a vacuum, and we have to find the value of r, the ordinate of the true logarithmic curve at the given point.

The logarithmic curve is defined by the equation

$$c \log \frac{r_1}{r_0} = t_1 - t_0 = \frac{\Delta}{\log 2} \log \frac{r_1}{r_0}.$$

Let

$$r_0 = (r_1 - 0°{\cdot}1).$$

To find the value of r_v corresponding to a given r_a (r_v vacuum, r_a air), we require to compute the value of $t_1 - t_0$, employing $\Delta_a = 294 - g\sqrt{r}$ in the equation

$$\frac{\Delta_a}{\log 2} \log \frac{r_a}{(r_a - 0^\circ\cdot 1)} = t_1 - t_0;$$

then, with this value of $t_1 - t_0$, and with $\Delta_v = 294$, find the value of r_v in the equation

$$t_1 - t_0 = \frac{\Delta_v}{\log 2} \cdot \log \frac{r_v}{(r_v - 0^\circ\cdot 1)}.$$

The direct equation is

$$\Delta_a \left\{\log r_a - \log (r_a - 0^\circ\cdot 1)\right\} = \Delta_v \left\{\log r_v - \log (r_v - 0^\circ\cdot 1)\right\}$$

and

$$\frac{\Delta_a}{\Delta_v} = 1 - \frac{g}{294}\sqrt{r_a} = 1 - \frac{\sqrt{r_a}}{17\cdot 131}.$$

Hence r_v may be ascertained by inspecting the differences of a table of logarithms; and it was from these that a scale was constructed for reducing the values of r taken in air to what they would be if taken in a vacuum, where the emission of heat was by radiation alone.

The cooling of the sun thermometer in air when fixed in its place in the tube, as in fig. 1, was found to be exactly the same as when fixed in the cylinder, fig. 2, unexhausted.

A chemical thermometer with cylindrical reservoir was tried in the vacuum-bath, and the cooling was found to take place exactly in the logarithmic curve. It is difficult to adjust the vacuum-bath in time to observe a high value of r, but good observations were obtained from $r = 190^\circ$ downwards; so there is little doubt that the law of cooling by radiation is general and independent of the shape of the cooling body. I purpose extending these observations with different surfaces. One result is interesting, as showing the perfect reciprocity of the radiation, viz. a gilt bulb radiating against a blackened metallic surface loses heat at the same rate as a blackened bulb against a bright metallic surface; the rate being slower than when both are blackened.

Another fact that it is well to keep in view is that, although the uncoated glass bulb radiates as quickly as the same coated with black, it does not absorb the incident rays of heat to the same degree; nearly one half being reflected without entering the glass.

Observations on Solar Radiation.

	Apparent Time. Latitude, 55° 58′ N. Longitude, 0h 12m 44s W.	Observed Values of r.	Ditto corrected for Talc Film.	Correction to Reduce to a Vacuum.	Value of r Reduced to a Vacuum.	Reciprocal of Ditto.	Apparent Altitude of Sun's Centre.	Cosecant of Apparent Zenith Distance.	Remar
		r_o	r_a	p	r_v	$\frac{1}{r_v}$	App. Alt.		
1861.	h m	°	°	°	°		° ′		
July 28	4 25 P.M.	17·5	20·6	+7·4	28·0	·0357	28 49	2·075	Bulb coated with lamp-black and turpentine; surface moist.
	4 36	16·5	19·5	6·8	26·3	·0380	27 16	2·183	
	4 56	15·5	18·3	6·2	24·5	·0408	24 30	2·411	
	5 26	14·0	16·5	5·2	21·7	·0461	20 19	2·880	
	6 18	13·2	15·5	4·7	20·2	·0495	13 11	4·385	
	7 26	7·2	8·5	1·7	10·2	·0980	4 27	12·888	
30	6 36 P.M.	11·8	13·9	+3·9	17·8	·0562	10 41	5·394	
	6 45	10·8	12·7	3·3	16·0	·0625	9 12	6·255	
	7 13	6·6	7·8	1·4	9·2	·1087	5 44	10·010	
31	Noon	23·0	27·2	+11·4	38·6	·0259	52 20	1·263	Extra fav conditio
	5 41 P.M.	15·0	17·7	5·8	23·5	·0425	17 38	3·301	Ditto.
	6 6	14·0	16·5	5·2	21·7	·0461	14 3	4·119	
	6 29	13·0	15·3	4·6	19·9	·0502	11 6	5·194	
	7 18	9·0	10·6	2·5	13·1	·0763	4 36	12·47	From July to Aug. the bul with C and g tion; su
	7 34	6·0?	7·1	1·3	8·4	·1190	2 52		
Aug. 1	9 51 A.M.	20·5+?	24·2	+9·5	33·7	·0297	44 58	1·415	
4	11 1 A.M.	20·0	23·6	9·1	32·7	·0306	49 35	1·313	
	6 36 P.M.	11·3	13·4	3·6	17·0	·0588	9 15	6·221	
5	Noon	20·2	23·8	9·2	33·0	·0303	51 0	1·287	Extra fav
B	3 44 P.M.	11·3	13·3	3·6	16·9	·0592	33 14	1·825	Bulb unc
B	4 30	9·7	11·4	2·7	14·1	·0709	27 10	2·190	Ditto.

All the above, taken with thermometer Y in the sun, and its correction for air, has been assumed to be the same as that experimentally determined for thermometer X in the subsequent observations.

In the following observations the thermometer in sun was X, with bulb coated with China ink:—

		r_o	r_a	p	r_v	$\frac{1}{r_v}$	App. Alt.	cosec.	
1861.	h m	°	°	°	°		° ′		
Aug. 9	3 34 P.M.	14·4	17·0	+5·5	22·5	·0444	33 7	1·830	
10	8 50 A.M.	15·2	17·9	+5·9	23·8	·0420	35 56	1·704	Taken fr secutiv 18 obse
	9 8	15·5	18·3	6·1	24·4	·0410	38 5	1·621	
	9 23	16·2	19·1	6·6	25·7	·0389	39 48	1·562	

81.	h m	r_o	r_a	p	r_v	$\frac{1}{r_v}$	App. Alt.	cosec.	
		°	°	°	°		° ′		
13	4 56 P.M.	12·8	15·1	+4·5	19·6	·0510	21 1	2·787	Not less, perhaps greater value of r.
	6 56	4·8	5·7	0·9	6·6	·1515	4 37	12·42	
	7 27	2·2	2·6	0·3	2·9	·3448	0 53		Sunset.
15	6 1 P.M.	9·5	11·2	2·7	13·9	·0719	11 25	5·05	
	7 4	3·8	4·5	0·6	5·1	·1961	3 4	18·69	
16	5 16 A.M.	4·4	5·2	0·8	6·0	·1667	5 29	10·465	Sun rises perfectly clear of clouds.
	9 39	14·6	17·2	5·6	22·8	·0439	39 51	1·561	
	11 3	15·0	17·7	5·8	23·5	·0425	46 20	1·382	
21	7 20 A.M.	9·8	11·6	2·9	14·5	·0690	19 0	3·071	
	7 40	10·7	12·6	3·3	15·9	·0629	21 45	2·698	
	8 0	11·6	13·7	3·8	17·5	·0571	24 29	2·413	
	8 20	12·3	14·5	4·2	18·7	·0535	27 9	2·191	Consecutive series graphically projected and equalised.
	8 40	13·0	15·3	4·6	19·9	·0502	29 45	2·015	
	9 0	13·5	15·9	4·9	20·8	·0481	32 14	1·874	
	9 20	13·8	16·2	5·0	21·2	·0472	34 37	1·760	
	9 40	14·1	16·6	5·3	21·9	·0457	36 50	1·668	
	h m s								
0	6 21 16 P.M.	6·6	7·7	+1·4	9·1	·1099	7 21	7·817	
	6 23 16	6·5	7·6	1·4	9·0	·1111	7 4	8·128	
	6 24 31	6·4	7·5	1·4	8·9	·1124	6 55	8·304	
	6 26 16	6·1	7·2	1·3	8·5	·1177	6 41	8·592	
	6 27 16	6·0	7·1	1·2	8·3	·1205	6 33	8·767	Consecutive series not equalised.
	6 28 36	6·1	7·2	1·3	8·5	·1177	6 22	9·018	
	6 31 0	5·7	6·7	1·1	7·8	·1282	6 2	9·514	
	6 37 16	4·8	5·7	0·8	6·5	·1538	5 12	11·034	
	6 39 0	4·7	5·6	0·8	6·4	·1562	4 59	11·512	
		Small cloud passes over the sun.							
	6 43 56	3·4	4·0	0·5	4·5	·2207	4 22	13·134	
	6 45 46	3·3	3·9	0·5	4·4	·227	4 5		
	6 47 16	3·2	3·8	0·5	4·2	·235	3 54		
	6 49 16	3·0	3·6	0·5	4·0	·249	3 38		
	6 51 0	2·8	3·3	0·4	3·7	·272	3 25		
	6 52 16	2·7	3·1	0·3	3·5	·287	3 15		
	6 54 0	2·4	2·9	0·3	3·2	·312	3 2		
	6 55 45	2·2	2·6	0·3	2·9	·348	2 48		
	6 58 46	1·9	2·2	0·2	2·4	·408	2 30		
	7 1 16	1·6	1·9	0·2	2·1	·483	2 7		
	7 4 0	1·1	1·3	0·1	1·4	·714	1 48		
28	Noon	12·5	14·8	4·3	19·1	·0524	43 42	1·447	
	0 44 P.M.	13·2	...	...	...	...	...	...	r sensibly augments after culmination.

In the following, thermometer Y was in sun, with its bulb coated with lamp-black in gold size:—

1861.	h m	r_o	r_a	p	r_v	$\frac{1}{r_v}$	App. Alt.	cosec.
		°	°	°	°		° ′	
Aug. 6	8 7 A.M.	16·2	19·1	6·6	25·7	·0389	31 17	1·926
	9 8	18·0	21·2	7·7	28·9	·0346	42 21	1·484
	9 32	18·3	21·6	8·0	29·6	·0338	45 12	1·409

Note.—Referring to the method of computing the Sun's potential temperature, described in the proceedings of the Society for March 1860, and employing the same rule with R, the extra atmospheric value of r equal to 70° at Earth's mean distance, we arrive at 12,880,000° as the potential temperature of its radiating surface.*

If we expose the flame of a bat's-wing-jet to one ball of a differential thermometer, the effect is the same, whether the broad side or the narrow side of the flame is presented, as I have found on trial. Now the potential temperature being equal to the product of r by the reciprocal of the angular space occupied by the flame, it is in the one case about five times greater than in the other. In the same way we might compute the potential temperature of an angular space occupied by many thousand flames placed one behind the other, extending in a line from the observer, and probably we should find it cumulative in the ratio of the number of flames.

From observations I have made on gas flames with the radiation meter, fig. 1, it would seem to require about 4000 bat's-wing-flames ranged behind each other to give a potential equal to that of the Sun.

If the upper radiating matter of the Sun is in any degree transparent or permeable to radiation from lower strata, it is obvious that the *actual* temperature may thus be much below the *potential.*

26 *Royal Crescent, Edinburgh, November* 25, 1861.

Note on a Theorem of Jacobi's, in relation to the Problem of Three Bodies. By A. Cayley, Esq.

The following theorem of Jacobi's (*Comptes Rendus*, t. iii., p. 61 (1836)) has not, I think, found its way in an explicit form into any treatise of physical astronomy. The theorem is as follows, viz. "Consider the movement of a point without mass round the Sun, disturbed by a planet the orbit of which

* There is a typographical error in the *Monthly Notices*, page 201, line 32; for $x = 918000$, read $x = 9,180,000$.

is circular. Let $x\,y\,z$ be the rectangular co-ordinates of the disturbed body, the orbit of the disturbing planet being taken as the plane of $x\,y$, and the Sun as the centre of co-ordinates; let a' be the distance of the disturbing planet, $n'\,t$ its longitude, m' its mass, M the mass of the Sun: then we have, *rigorously*,

$$\frac{1}{2}\left[\left(\frac{dx}{dt}\right)^2+\left(\frac{dy}{dt}\right)^2+\left(\frac{dr}{dt}\right)^2\right]-n'\left(x\frac{dy}{dt}-y\frac{dx}{dt}\right)$$

$$=\frac{M}{(x^2+y^2+z^2)^{\frac{1}{2}}}+m'\left\{\frac{1}{(x^2+y^2+z^2-2\,a'\,(x\cos n'\,t+y\sin n'\,t)+a'^2)^{\frac{1}{2}}}\right.$$

$$\left.-\frac{x\cos n'\,t+y\sin n'\,t}{a'^2}\right\}+C.$$

This is therefore a new integral equation, which, in the problem of three bodies, subsists, as regards the terms independent of the excentricity of the disturbing planet, and which is rigorous as regards all the powers of the mass of such planet. In the *Lunar Theory* the Earth must be substituted in the place of the Sun, and the Sun taken as the disturbing planet."

To prove the theorem, as expressed in polar co-ordinates, I take the equations of motion in the form in which I have employed them in my "Memoir on the Theory of Disturbed Elliptic Motion" (*Memoirs*, vol. xxvii. p. 1 (1859)), viz.

$$\frac{d}{dt}\,\frac{dr}{dt}-r\cos^2 y\left(\frac{dv}{dt}\right)^2-r\left(\frac{dy}{dt}\right)^2+\frac{n^2a^3}{r^2}=\frac{d\,\Omega}{dr},$$

$$\frac{d}{dt}\left(r^2\cos^2 y\,\frac{dv}{dt}\right)=\frac{d\,\Omega}{dv},$$

$$\frac{d}{dt}\left(r^2\,\frac{dy}{dt}\right)+r^2\cos y\sin y=\frac{d\,\Omega}{dy},$$

where

$$\Omega=m'\left\{\frac{1}{\sqrt{r^2+r'^2-2\,r\,r'\cos H}}-\frac{r\cos H}{r'^2}\right\};$$

or, since $\cos H=\cos y\cos(v-v')$, and the Sun is considered as moving in a circular orbit (i.e. $r'=a'$, $v'=n'\,t$), we have

$$\Omega=m'\left\{\frac{1}{\sqrt{r^2+a'^2-2\,r\,a'\cos y\cos(v-n'\,t)}}-\frac{r\cos y\cos(v-n'\,t)}{a'^2}\right\};$$

so that Ω is a function of r, v, y and of t, which last quantity enters only in the combination $v-n't$. Hence the complete differential coefficient of Ω is

$$\frac{d(\Omega)}{dt} = \frac{d'\Omega}{dt} - n'\frac{d\Omega}{dv},$$

where $\frac{d'\Omega}{dt}$ denotes, as usual, the differential coefficient in regard to the time, in so far as it enters through the co-ordinates r, v, y of the disturbed body.

We have, as usual,

$$\frac{d}{dt}\frac{dr^2+r^2(\cos^2 y\, dv^2+dy^2)}{dt^2} = \frac{d'\Omega}{dt};$$

but from the foregoing equation,

$$\frac{d'\Omega}{dt} = \frac{d(\Omega)}{dt} + n'\frac{d\Omega}{dv}$$

$$= \frac{d(\Omega)}{dt} + n'\frac{d}{dt}\left(r^2\cos^2 y\frac{dv}{dt}\right);$$

and, substituting this value, transposing, and integrating, we have

$$\left(\frac{dr}{dt}\right)^2 + r^2\left\{\cos^2 y\left(\frac{dv}{dt}\right)^2 + \left(\frac{dy}{dt}\right)^2\right\} - n'r^2\cos^2 y\frac{dv}{dt} = \Omega + \text{C},$$

which is Jacobi's equation expressed in terms of the co-ordinates r, v, y.

M. de Pontécoulant, in his *Lunar Theory* (1846), where the solar excentricity is neglected, writes (p. 91),

$$\int d'\text{R} = \text{R} + m\int\frac{d\text{R}}{dv}dt,$$

($n' = m\,n = m$, since n is there put equal to unity); and combining this with the equation (p. 43),

$$\frac{r^2\,dv}{(1+s^2)\,dt} = h + \int\frac{d\text{R}}{dv}dt,$$

we have

$$\int d'\text{R} = \text{R} - mh + \frac{mr^2\,dv}{(1+s^2)\,dt};$$

and substituting this value of $\int d'\mathrm{R}$ in the integral of *Vis Viva* (p. 41),

$$\left(\frac{dr}{dt}\right)^2 + \frac{r^2\,dv^2}{(1+s^2)\,dt^2} + \frac{r^2\,ds^2}{(1+s^2)^2\,dt^2} - \frac{2}{r} + \frac{1}{a} = 2\int d'\mathrm{R},$$

we have what is, in fact, Jacobi's equation.

A Third Memoir on the Problem of Disturbed Elliptic Motion. By A. Cayley, Esq. (Abstract.)

The object of the Memoir is to obtain the differential equations for determining

r, the radius vector,
v, the longitude,
y, the latitude,

of the disturbed body, when the last two co-ordinates are measured in respect to an arbitrarily varying plane (which, however, to fix the ideas, is called the variable ecliptic) and departure-point, or origin of longitudes therein. This is very readily effected by means of an expression for the *Vis-Viva* function given in my "Supplementary Memoir on the Problem of Disturbed Elliptic Motion," *Mem. Roy. Ast. Soc.*, vol. xxviii. pp. 217–234 (1859).

Neglecting the squares of the variations of the variable ecliptic, and also the products of the variations by sin y or $\frac{dy}{dt}$, then (as might be expected) it is found that the equations for r and v are the same as for a fixed ecliptic, and the equation for y is found in a simple form, which is ultimately reduced to coincide with that obtained for the lunar theory by Laplace in the seventh book of the *Mécanique Céleste*, and which is used by him to show that the effect of the variation of the ecliptic on the latitude of the Moon (as measured from the variable ecliptic) is insensible. And it is shown conversely how the approximate formula of the Memoir may be obtained by a process similar to that made use of in the *Mécanique Céleste.*

On the Circularity of the Sun's Disk. By G. B. Airy, Esq., Astronomer Royal.

It has been proposed lately to prepare an apparatus for the purpose of examining whether the Sun's disk is really circular, and, in particular, for ascertaining whether the diameters nearly perpendicular to the ecliptic are equal to those nearly parallel to the ecliptic. I would not by any means discourage the trial of such apparatus, but I would unhesitatingly express my opinion that the result of the trial would be to show whether the apparatus is or is not trustworthy, and not to give any new information regarding the measure of the Sun's diameters in any degree comparable to that which we already possess.

Perhaps few persons except professional astronomers are aware of the enormous amount of evidence which already exists in reference to the values of the Sun's diameters, and of the way in which this evidence is growing every day in the ordinary routine of meridional observations. To make this fully understood, I will here explain what is prepared in the *Nautical Almanac*, what is observed at the Royal Observatory, how the observations are reduced, and how the comparison of the reduced observations with the numbers of the *Nautical Almanac* bears upon the subject now before us.

For the calculations of the *Nautical Almanac*, an assumption is made as to the numerical value of the Sun's diameter, as seen when the Earth is at its mean distance from the Sun. It matters not whether this assumed diameter is or is not correct, provided that it be used consistently in all the calculations of each year; and it matters not whether it be or be not changed from year to year, provided that each volume contain a statement of the assumed diameter which has actually been used in the calculations of that volume. Thus the assumed value of Sun's diameter, as seen at Earth's mean distance, in the *Nautical Almanacs* from 1836 to 1852, was $32' \, 1''\cdot 80$; that in the subsequent *Nautical Almanacs* is $32' \, 3''\cdot 64$.

With the diameter thus assumed, two sets of numbers are computed in the *Nautical Almanac*. One is, the apparent diameter (or semidiameter) of the Sun at noon on every day; this is found by merely altering the assumed diameter in the inverse proportion of the Earth's varying distance from the Sun. The other is, the duration of passage of the Sun's diameter across the meridian, or the measure of the sidereal time which elapses between the passage of the Sun's western limb and its eastern limb; this is found, from the apparent diameter of the day, by introducing the consideration of the Sun's declination, and of the Sun's motion in right ascension. And, these numbers being prepared, it is evident that we have elements which correspond very closely with facts that may be

observed, the elements being essentially based on the supposition that the Sun's disk is circular.

Corresponding to these two classes of computed elements, we have two classes of facts observed at the Royal Observatory and at other Observatories. One is, the zenith distance of the Sun's upper limb and that of the Sun's lower limb. When each of these is corrected separately for refraction and parallax, the true results of geocentric observation are obtained; and the difference between them gives the observed *vertical* diameter of the Sun on the day of observation. The other is, the sidereal time shown by the transit-clock at the instant of transit of the Sun's western limb, and that at the transit of the Sun's eastern limb; the difference between these gives the observed duration of passage of the Sun's *horizontal* diameter across the meridian on the day of observation.

Now if we compare each of these numbers separately (namely, the observed vertical diameter and the observed duration of passage of horizontal diameter) with the corresponding numbers in the *Nautical Almanac*, and if we omit consideration of chance-errors of observation, the effect of which may be supposed to be nearly eliminated in the mean of many observations, the following results ought to hold:—If the Sun's disk is really circular, and if the *Nautical Almanac* assumed diameter at mean distance is correct, then the observed vertical diameter will agree with the *Nautical Almanac* diameter for the day, and the observed duration of passage will agree with that of the *Nautical Almanac*. If the Sun's disk is really circular, but the assumed diameter incorrect, then neither of the compared measures will agree with the corresponding computation of the *Nautical Almanac;* each discordance (one of vertical diameter, the other of duration of passage of horizontal diameter) will indicate a numerical value of correction to be applied to the assumed diameter; but the two numerical values will absolutely agree. But if the Sun's disk is not really circular, then it is impossible that the comparison of observed vertical diameters on the one hand, and of observed durations of passage of horizontal diameters on the other hand, with elements computed on the supposition that the Sun is circular, can indicate the same correction to the assumed semidiameter.

All that is necessary, therefore, for ascertaining whether the Sun's horizontal diameter and the Sun's vertical diameter are equal, is, every day to compare the Sun's observed vertical diameter with the *Nautical Almanac* diameter, and the observed duration of passage of Sun's horizontal diameter with the *Nautical Almanac* duration, and to infer separately from these the correction to be made to the *Nautical Almanac* assumed diameter. If the two results agree, the horizontal and vertical diameters are equal.

Now these comparisons are made every day in the routine of the Royal Observatory, and their results will be found in

one of the late sections of each volume of the printed *Greenwich Observations*, as well as in the more extensively distributed *Results of the Greenwich Observations*, which contain that section; and the means of the numbers for each year are given in the Introduction to each volume. By extracting these numbers, the following table is formed. I have thought it necessary to divide the table into three parts, distinguished by the following circumstances:—From 1836 to 1850, the 4-inch telescope (I believe Dollond's) of the Mural-Circle was used for the vertical diameters, and the 5-inch telescope (Dollond's) of the Transit for the horizontal passages; the diameter used in the computations of the *Nautical Almanac* was 32′ 1″·80. Through 1851 and 1852, the 8-inch telescope (Simms') of the Transit-Circle was used for both measures, the *Nautical Almanac* assumed diameter being still 32′ 1″·80. From 1853 to 1860, the telescope of the transit-circle was used for both measures, but the *Nautical Almanac* assumed diameter was 32′ 3″·64.

Apparent Errors of the Duration of Passage of the Sun's Horizontal Diameter, and of the Sun's Vertical Diameter, as computed in the Nautical Almanac.

Year.	No. of Obs. of Horizontal Diameter.	Mean Value of N.A. − Ob.	No. of Obs. of Vertical Diameter.	Mean Value of N.A. − Ob.
		s		″
1836	104	−0·17	116	−1·50
1837	92	−0·18	122	−1·85
1838	108	−0·14	115	−1·53
1839	103	−0·14	114	−0·94
1840	104	−0·18	112	−1·60
1841	102	−0·14	109	−1·32
1842	116	−0·14	121	−1·54
1843	99	−0·14	107	−1·84
1844	102	−0·18	117	−1·50
1845	100	−0·17	113	−1·32
1846	92	−0·10	101	−2·09
1847	89	−0·05	89	−2·98
1848	94	−0·06	102	−2·06
1849	103	−0·11	101	−2·40
1850	94	−0·11	86	−2·18
1851	87	−0·08	106	−0·71
1852	103	−0·12	112	−1·39
1853	78	0·00	86	+0·58
1854	109	+0·09	111	+1·29
1855	84	+0·07	93	+0·65

Year.	No. of Obs. of Horizontal Diameter.	Mean Value of N.A.—Ob.	No. of Obs. of Vertical Diameter.	Mean Value of N.A.—Ob.
		s		″
1856	104	+0·10	109	+1·17
1857	113	+0·07	123	+0·99
1858	126	+0·07	132	+0·92
1859	109	+0·08	125	+0·99
1860	72	+0·09	72	+1·64

If we take the sums of the numbers of observations and the means of the errors, and if we remark that the mean error of the horizontal diameter in arc may be obtained from the mean error of the duration of passage without sensible error by multiplying by 14, we obtain the following numbers:—

Period.	No. of Obs.	Mean Error of N.A. Duration of Passage.	Mean Error of N.A. Horizontal Diameter.	No. of Obs.	Mean Error of N.A. Vertical Diameter.
		s	″		″
1836 to 1850	1502	−0·134	−1·88	1625	−1·78
1851 and 1852	190	−0·100	−1·40	218	−1·05
1853 to 1860	795	+0·071	+0·99	851	+1·03

If we change the signs of these errors, to form corrections, and apply them to the assumed diameter at mean distance of the Earth from the Sun (namely, 32′ 1″·80 to the end of 1852, and 32′ 3″·64 from the beginning of 1853), to produce a corrected diameter of the Sun at mean distance, we form the following table:—

Instruments employed.	Period.	No. of Obs.	Corrected Horizontal Diameter.	No. of Obs.	Corrected Vertical Diameter.
			′ ″		′ ″
Transit and Mural Circle ...	1836 to 1850	1502	32 3·68	1625	32 3·58
Transit Circle ...	{1851 and 1852}	{190}	{32 3·20}	{218}	{22 2·85}
	{1853 to 1860}	{795}	{32 2·65}	{851}	{32 2·61}
	Mean 1851 to 1860	985	32 2·76	1069	32 2·66

Thus the observations with both classes of instruments, in aggregate number 2487 for horizontal diameter and 2694 for vertical diameter, agree in showing that the horizontal diameter exceeds the vertical diameter by only 0″·1, a quantity smaller than we can answer for in these or in any other methods of observation.

A consideration of the number and excellence of the observations fully supports the view which I have stated in introducing this subject: that the only result which could be deduced from the trial of new apparatus would be to test the apparatus, but not to add to the certainty of the conclusion as to the equality of diameters.

The diameter adopted now in the *Nautical Almanac* was inferred from observations made with the Transit and Mural Circle, and therefore agrees very closely with that here deduced from the use of those instruments. That obtained with the Transit-Circle is less by $0''\cdot93$.

Royal Observatory, Greenwich,
Dec. 28th, 1861.

Table of Comparative Number of Observations of Small Planets. By the Astronomer Royal.

For my own guidance, in arranging the course of observations of the Royal Observatory, I lately thought it necessary to draw out a Table exhibiting the comparative number of observations of the Small Planets between *Mars* and *Jupiter*, on the one hand, as made at all Observatories (in the aggregate) except that of Greenwich, and on the other hand as made at Greenwich. For this purpose, I fixed upon the year 1858, as the latest for which I might presume all observations to be published; and my Assistant, Mr. Carpenter, examined every record to which I have access. The result may, perhaps, be interesting to the Society.

For Small Planets discovered before the middle of 1857.

Name of Planet.		Number of Observatories.	Number of Observations. Equatoreal.	Number of Observations. Meridional.	Observatory, Greenwich.	Number of Meridional Observations.
Ceres	①	2	0	21	,,	22
Pallas	②	2	0	12	,,	29
Juno	③	2	0	24	,,	27
Vesta	④	3	0	24	,,	31
Hebe	⑥	4	0	11	,,	19
Iris	⑦	5	14	13	,,	21
Flora	⑧	7	13	47	,,	23

Name of Planet.		Number of Observatories.	Number of Observations. Equatoreal.	Meridional.	Observatory, Greenwich.	Number of Meridional Observations.
Metis	(9)	1	0	2	,,	16
Hygeia	(10)	0	0	0	,,	1
Parthenope	(11)	3	4	10	,,	13
Egeria	(13)	4	7	8	,,	17
Irene	(14)	0	0	0	,,	6
Eunomia	(15)	4	1	29	,,	22
Psyche	(16)	5	18	7	,,	11
Thetis	(17)	0	0	0	,,	1
Melpomene	(18)	5	10	4	,,	21
Fortuna	(19)	4	6	6	,,	22
Massilia	(20)	6	14	19	,,	21
Lutetia	(21)	1	5	0	,,	11
Calliope	(22)	2	6	2	,,	8
Thalia	(23)	6	4	16	,,	18
Themis	(24)	6	25	8	,,	7
Phocæa	(25)	1	1	0	,,	0
Proserpine	(26)	5	19	4	,,	6
Euterpe	(27)	5	6	33	,,	16
Bellona	(28)	1	34	0	,,	0
Amphitrite	(29)	5	6	9	,,	24
Urania	(30)	5	20	6	,,	22
Pomona	(32)	2	8	0	,,	4
Polyhymnia	(33)	1	4	0	,,	0
Atalanta	(36)	1	1	0	,,	0
Fides	(37)	4	16	0	,,	0
Leda	(38)	3	10	0	,,	2
Lætitia	(39)	4	12	11	,,	32
Daphne	(41)	1	1	0	,,	0
Iris	(42)	0	0	0	,,	2
Ariadne	(43)	3	14	0	,,	11
Nysa	(44)	3	13	1	,,	4
		Sum	292	327		490

For Small Planets discovered after the middle of 1857.

Name of Planet.		Number of Observatories.	Number of Observations. Equatoreal.	Number of Observations. Meridional.	Observatory, Greenwich.	Number of Meridional Observations.
Eugenia	(45)	3	11	0	,,	0
Aglaia	(47)	3	20	0	,,	0
Doris	(48)	2	11	0	,,	0
Pales	(49)	2	11	0	,,	0
Virginia	(50)	3	14	0	,,	0
Nemausa	(51)	5	57	0	,,	7
Europa	(52)	10	62	17	,,	7
Calypso	(53)	8	50	0	,,	0
Alexandra	(54)	6	40	0	,,	2
Pandora	(55)	7	83	0	,,	3
		Sum	359	17		19

It appears from this table that the observations made in the first year of a planet's discovery are almost exclusively extrameridional; but that in subsequent years the meridional observations slightly preponderate. And with regard to these (on which probably the accurate theory and even the permanent retention of planets in the list of our solar system will ultimately depend), it appears that a single Observatory of established regularity of system contributes a greater number of observations than the aggregate of all the others. As regards Greenwich, the increase in the number of small planets has now made it necessary to diminish the attention given to each; but it is probable that the ratio for the different Observatories will not be materially altered.

It appears necessary, therefore, that Observatories of fixed system should still retain these bodies in the list of those to be regularly followed. The observations, however, are extremely onerous, and it is much to be wished that they could be somewhat distributed. Hitherto my efforts to effect an arrangement for this purpose have entirely failed.

Royal Observatory, Greenwich,
1861, *December* 19.

Results of Meridional Observations of Small Planets; and Phenomena of Jupiter's Satellites; observed at the Royal Observatory, Greenwich, during the month of December, 1861.

(*Communicated by the Astronomer Royal.*)

Victoria ⑫.

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Dec. 2	10 0 17·5	2 47 10·45	73 39 49·17
5	9 46 38·3	2 45 18·73	73 59 10·78
19	8 46 25·3	2 40 7·65	75 9 7·65

Irene ⑭.

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Dec. 2	9 14 48·4	2 1 33·86	87 6 14·49
5	9 1 34·2	2 0 7·17	87 0 49·32

Europa ㊾.

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1861, Dec. 2	7 49 48·3	0 36 19·82	95 34 18·52

All the observations of N.P.D. have been corrected for refraction and parallax.

No occultations of Stars by the Moon were observed.

Phenomena of Jupiter's Satellites.

Day of Observation. 1861.	Satellite.	Phenomenon.	Mean Solar Time. h m s	Observer.
Dec. 1	III	Ecl. reappearance (*a*)	14 27 24·3	C.
8	III	Ecl. disappearance	15 6 42·7	R.
8	III	Ecl. reappearance	18 23 34·1	R.
13	IV	Egress first cont. (*b*)	18 33 29·4	M. D.
13	IV	,, last cont. (*b*)	18 38 38·6	M. D.

(*a*) Unsatisfactory from cloud. (*b*) The planet's image much diffused.

The initials C., M. D., and R., are those of Mr. Criswick, Mr. Dolman, and Mr. Roberts.

Observations in Australia of the Transit of Mercury of the 12th November, 1861.

Mr. Scott, in a letter dated Observatory, Sydney, November 22d, 1861, writes:—

"The transit of *Mercury* which occurred on the 12th instant was only partially observed, on account of the cloudy state of the sky. The time of internal contact was $3^h\ 24^m\ 34^s$ Sydney mean time. The egress occurred after sunset."

And he encloses the following notice, received from Mr. Todd, at Adelaide:—

"I make time of total ingress, $2^h\ 34^m\ 12^s$.

	h	m	s
First contact, egress......	6	30	29
Last contact, egress......	6	32	19

"The first two may be considered good, especially the ingress. The last is uncertain, the Sun being low down and boiling."

Mr. Ellery, in a letter dated Observatory, Williamstown, Victoria, November 25th, 1861, writes:—

"We observed the ingress and a portion of the transit of *Mercury* across the Sun's disk on the 12th instant.

"It was cloudy most of the day, but the weather cleared up about 1 P.M., leaving us an almost clear sky until some time after the ingress of the planet. The egress took place after sunset to us.

"I observed the first contact, or rather *indentation*, at $2^h\ 58^m\ 2^s$. The first glimpse I got of the notch I estimated, by its subsequent motion, to be about 8^s after the first contact had taken place. The internal contact was lost on account of a passing cloud.

"As I possessed no other than a rough position-micrometer, I could make no measures during the transit."

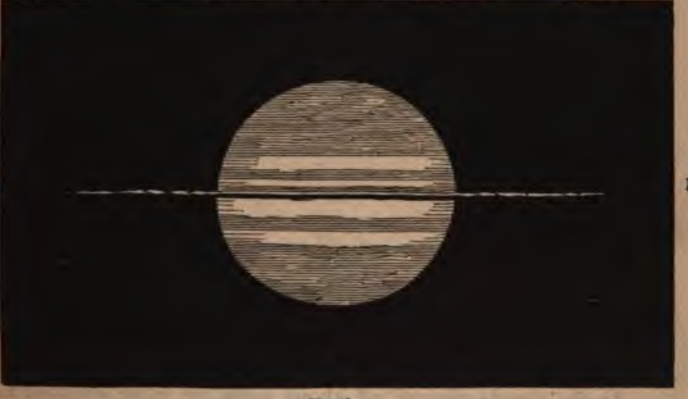
The longitude of the observatory is $9^h\ 39^m\ 40^s{\cdot}01$ E., lat. $37^\circ\ 52'\ 8''$ S.

Note on Two Drawings of Saturn. By Capt. W. S. Jacob.

Two drawings of *Saturn*, by Captain Jacob, were exhibited at the meeting in December. Captain Jacob writes:—

"No. 1 was taken on the morning of November 12th, shortly before the disappearance of the ring, as seen in Dr. Lee's telescope at Hartwell. I cannot say how far the inequalities in the ring were due to want of definition. The atmosphere was not in prime condition, and scarcely bore the power of 240; yet, when the definition seemed at its best by occasional glimpses, the inequalities were the most conspicuous.

South.

West.  East

North.

South.

West.  East.

North.

"No. 2 was taken at York on the morning of the 4th Dec.

with the 9-inch object-glass, which Messrs. Cooke and Sons have been preparing for my equatoreal. The excellence of its defining power may be judged of from the fact of its separating the dark streak across the planet into two parts, with an almost inconceivably fine line of light between, viz., the ring itself and its shadow. The breadth of the former could not have been much more than $0''\cdot04$.

"Only four satellites could be seen, viz., *Titan*, at some distance, and the three shown in the drawing, of which the outermost is *Tethys*, and the other two, probably, *Dione* and *Enceladus*.

"*Hartwell, near Aylesbury,*
December 11, 1861."

The Solar Eclipse of the 31*st December*, 1861, *observed at Kilkenny House, Sion Hill, Bath.* By R. W. H. Hardy, Esq., R.N.

As the clouds cleared off about noon, we were enabled to view the eclipse uninterruptedly. The moment of first contact was not accurately noticed. It appeared to take place at $1^h\ 45^m$ G.M.T. Soon after the eclipse began, and for some time afterwards, the overlapping surface of the Moon was covered over with a soft grey tint, which terminated on the advancing edge in a narrow band of deep purple. Concurrently with this purple band, there appeared in advance of the Moon's edge, but concentric with it, at a short distance, a bright gleam of light brighter than the solar disk. This light was separated from the Moon's edge by a narrow pale green shadow, which softened into the former. This is also the character of all shadows from objects on our Earth. At 2^h the Moon's edge undulated rapidly, while the Sun's edge remained comparatively tranquil. About this time also, the outline of the Moon appeared to form an irregular curvature, bulging out at the edge *a*, figure 1. This irregularity, however, diminished as the Moon advanced till she reached the central line, when it ceased; but began again to increase from this epoch till it reached a second maximum near the point *a′*, figure 3, at 3^h G.M.T. Before this, at $2^h\ 15^m$, a bright yellow-green light reflected from the Moon's edge and contiguous surface attracted our notice, which not only brought out our satellite in strong relief, but also showed the lunar surface beautifully foreshortened, especially so at $3^h\ 35^m$. With respect to the apparent undulations of the edges of the Sun and Moon, they were about equal when our satellite reached the line of centres, and at their

greatest difference of velocity when she attained the two opposite points *a* and *a'*, figures 1 and 3. When the moon reached the middle of the eclipse, as shown in figure 2, and by carefully excluding every ray of direct solar light, the Moon's edge was traceable upwards to a considerable distance from both cusps, as if illuminated by a faint twilight. The conclusion of the eclipse was not seen, owing to the thickness of the sky about that time.

My telescope is a 12-inch Newtonian reflector; the eyepiece I used on the occasion was an inverting one, and the power employed 60 times, which takes all the sun into the field. The projecting glass was a neutral tint, which does not materially affect the appearance of the colour of natural objects.

Inverted Images.

Fig. 1. Fig. 2. Fig. 3.

Commencement, Middle, Termination.

Eclipse of the Sun of 31*st December*, 1861, *observed at Nice.* By C. G. Talmage, late of the Greenwich and Regent's Park Observatories, Assistant to T. Coventry, Esq., 5 Tavistock Square.

(*Communicated by Mr. Hind.*)

The instrument used was a 5-foot Equatoreal, the stand and metal-work being constructed by Troughton and Simms; but the object-glass, which has a clear aperture of 4 inches, is of Munich manufacture.

Every precaution was taken that the first contact should be accurately observed; and the time, thermometer, and barometer observations are put by themselves, as being easier for reference.

At the total immersion of spot (*b*), it seemed suddenly to blaze forth, and quite a mauve tint was visible all round it. I

have only seen one instance on record of such an occurrence (Hind's *Solar System*, p. 65). The Moon's limb presented no irregularities. As the obscuration advanced to its greatest phase, a very sensible difference took place in the temperature of the atmosphere. At about $3^h\,25^m$ M.T. a very cold north-east wind sprung up, and blew for about half an hour—so cold that most of the visitors on the promenade (Promenade des Anglois) returned home, and at the greatest phase only a few gentlemen with coloured glasses were left. At this time, also, *Venus* shone forth with great brilliancy; *Arcturus*, *Antares*, and α *Aquilæ* were looked for without success. At $3^h\,45^m$, a remarkable phenomenon presented itself on the surface of the Moon: there appeared a semicircular streak of red light close to the limb, gradually diminishing to two abrupt points. About this time the landscape had a very peculiar tinge: the mountains at a great distance appeared of a deep blue tinge, and seemed to stand out with unnatural distinctness. Spot (*e*) was only just grazed by the Moon's limb. The Sun unfortunately setting before the eclipse had ended, we had not an opportunity of observing the time of last contact.

	h m s
Nice M.T. of first contact............	2 27 22·80
Time of first contact of spot (*a*) ...	2 34 31
,, total immersion	2 34 45
Time of first contact of spot (*b*) ...	2 35 53
,, total immersion	2 36 36
Time of first contact of spot (*f*) ...	3 16 30
,, central bisection	3 17 16
,, total immersion	3 18 0
Time of total immersion of spot (*g*)	3 20 5
Time of first contact of spot (*c*) ...	3 21 40
,, total immersion	3 24 0

	h m s
Time of first contact of spot (*d*) ...	3 26 50
,, total immersion	3 29 30
Time of total emersion of spot (*c*)	3 38 35

Time.	Barom.	Therm. in Shade.	Therm. in Sun.
	in	°	°
0·0	30·327	68·8	93·1
0·30	30·327	69·8	90·0
1·15	30·315	67·7	75·5
2·20	30·305	65·7	73·3
2·40	30·300	64·5	72·5
3·10	30·300	62·2	65·0
3·30	30·300	60·3	60·8
3·50	30·300	59·0	59·0
4·5	30·300	57·8	58·8

P.S. The observations were made at the Grand Hotel Chauvain.

Occultations of Stars by the Moon. Observed by C. G. Talmage, Esq.

The observations were made at the Grand Hotel Chauvain, Nice, with a 5-foot equatoreal, aperture 4 inches.

Occultation of R *Aquarii* on Moon's dark limb, January 4, 1862:—

The dark limb was beautifully defined; the star appeared to be bisected by, or hung in, the Moon's limb for 8^s or 10^s.

Nice mean time of disappearance = $7^h\ 34^m\ 3^s{\cdot}00$.

Occultation of 103 *Tauri* on Moon's dark limb:—
Star disappeared instantaneously. January 12, 1862.

Nice mean time of disappearance = $9^h\ 23^m\ 40^s{\cdot}60$.

Occultation of 1 *Geminorum* on Moon's dark limb:—
Star very faint as it neared the Moon's limb. 1862, January 13.

Nice mean time of disappearance = $12^h\ 32^m\ 1^s{\cdot}00$.

Additions and Corrections to the Observations of Comet II., 1861. By the Rev. R. Main, Radcliffe Observer.

By inadvertence the observations of 1861, August 29, were omitted; they are as follows:—

	Greenwich M.T.	Apparent R.A.	Apparent N.P.D.
	h m s	h m s	° ′ ″
Aug. 29	8 32 31·3	15 30 57·77	46 12 12·6
	8 47 28·0	15 31 0·90	46 12 11·6
	9 10 4·4	15 31 1·17	46 12 33·4

The following corrections are to be made:—

Page 51, July 5. The N.P.D.'s opposite the 2d and 3d observations of this day belong to the 3d and 4th observations.

Page 52, Aug. 6, 3d observation, the Greenwich mean time should be $11^h\ 38^m\ 20^s{\cdot}0$, instead of $11^h\ 38^m\ 2^s{\cdot}0$.

Page 54, July 14, 15, 16. The places of the two anonymous stars set down are only approximate, and have not been employed in the reductions.

Page 54, Aug. 19. *For* Radcliffe 3387, *read* Radcliffe 3385.

Radcliffe Observatory, Oxford,
1862, *Jan.* 20.

Observations and Elements of Comet III., 1861. Communicated by G. P. Bond, Director of the Observatory of Harvard College, Cambridge, U.S.

A telescopic comet was discovered at this observatory by Mr. H. P. Tuttle, at 3 A.M. Dec. 29th. The following observations and elements have been obtained:—

Observations of Comet.

[By a provisional reduction.]

	Cambridge M.T.	R.A.	Decl.
	h m s	h m s	° ′ ″
1861, Dec. 28	18 25 34	14 12 55·3	−5 12 39
„ „ 30	18 20 16	14 15 29·9	−1 24 42
1862, Jan. 1	18 37 18	14 18 39·0	+3 9 31

The following elements have been computed by T. H. Safford, Assistant at the Observatory:—

1861, Washington M.T. Dec 6·9867.

$\log q = 9{\cdot}92400.$

$$\omega^* = 331^\circ\ 39'{\cdot}10$$
$$\Omega = 145\ \ 8{\cdot}78, \text{ App. Eq., Jan. 1, 1862.}$$
$$i = 41\ \ 58{\cdot}40$$

Motion retrograde.

* Distance of the perihelion from the ascending node in the direction of motion.

The middle observation is represented as follows:—

	C — O.
$\delta\lambda \cos\beta$	$+0'{\cdot}19$
$\delta\beta$	$+0{\cdot}03$

The subjoined Ephemeris may, perhaps, be useful for the reduction of observations:—

18h Washington.	Comet's R.A.	Comet's Decl.	Log. Δ.
	° ′	° ′	
1862, Jan. 1	214 40	+ 3 8	9·775
3	215 37	8 36	9·714
5	216 49	15 9	9·675
7	218 19	22 59	9·638
9	220 18	32 3	9·609

About the 20th instant it will approach the north pole.

Observatory of Harvard College,
Jan. 3d, 1862.

The same Comet was observed at Pulkova:—

8th Jan. 1862 $14^h\,21'$ M. T. R.A. $218^h\,49^m$ Decl. $25^\circ\,22'$ N.

And at Altona:—

	M.T.	R.A.	Decl.
	h m s	h m s	° ′
18th Jan.	7 28 0	16 29 35	73 21 N.
19th „	6 23 45	17 9 37	76 42 N.

Minor Planet (59).

The name *Olympia* has been given to this planet.

ERRATA.

P. 38 (Mr. Lassell's Observations of the Transit of *Mercury*), *for* "Piazzi Stierna," *read* "Piazzi Slierna."

P. 40 (Prof. Chevallier's Account of the same Transit), immediately before Mr. Marth's Observations, *insert*, "But these observations, and especially those in declination, are regarded as sufficiently accurate only to show that the tables are nearly correct, the trembling of the Sun's limb rendering them uncertain."

CONTENTS.

Printed by Strangeways and Walden, Castle St. Leicester Sq. and Published at the Apartments of the Society, February 8, 1862.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXII. *February* 14, 1862. No. 4.

THE Annual General Meeting of the Society, Dr. LEE, President, in the Chair.

Arthur Cottam, Esq., 1 Whitehall Place;
Wm. Thynne Lynn, Esq., Superintendent of Computers, Royal Observatory, Greenwich;
The Hon. Samuel Cockburne, Governor of Montserrat, West Indies;
George Dollond, Jun., Esq., 59 St. Paul's Churchyard; and
Charles Mason, Esq., 16 Queen's Road, Regent's Park,

were balloted for and duly elected Fellows of the Society.

After the business was concluded, a Special General Meeting was held for the purpose of electing Miss Sheepshanks an Honorary Member of the Society, which was done accordingly.

Report of the Council to the Forty-second Annual General Meeting of the Society.

The Report of the Auditors, subjoined, will show the state of the finances:—

RECEIPTS.

	£	s.	d.
Balance of last year's account	276	19	3
By dividend on £2000 Consols	28	15	0
By ditto on £3500 new 3 per Cents	50	6	3
By ditto on £2100 Consols	30	6	5
Carried forward	£386	6	11

	£	s.	d.
Brought forward	386	6	11
By dividend on £3800 New 3 per Cents	54	17	3
On account of arrears of contributions	81	12	0
115 contributions (1861–62)	241	10	0
1 contribution (balance for 1862)	1	1	0
7 compositions	147	0	0
35 admission-fees	73	10	0
30 first year's contributions	57	15	0
3 contributions for 1863	6	6	0
Sale of Publications	70	2	0
By cash for India Hill Observatory	1000	0	0
	£2120	0	2

EXPENDITURE.

	£	s.	d.	£	s.	d.
Salaries:—						
Mr. Cayley, 1 year as Editor of the Society's Publications	60	0	0			
Mr. Williams, 1 year as Assistant-Secretary	100	0	0			
Ditto commission on collecting £531 16*s*.	26	0	0			
				186	0	0
Investments:—						
Investing £100 Consols				91	10	0
Taxes:—						
Property Tax, 1 year	4	7	6			
Assessed and Land, ditto	2	1	8			
				6	9	2
Bills:—						
Strangeways and Co., printers	415	15	0			
J. Basire, engraver	42	0	0			
Joyce, engraver	1	10	0			
C. Frodsham, clock	3	7	6			
Insurance (Sun Fire Office)	12	5	6			
L. Wyon, medals	57	15	0			
				532	13	0
Miscellaneous items:—						
Charges on books, and carriage of parcels	4	15	8			
Postage of *Monthly Notices*, letters, &c.	39	15	4			
Porter's and charwoman's work	24	13	6			
Tea, sugar, biscuits, &c. for evening meetings	13	13	0			
Waiters attending meetings	3	17	0			
Coals, &c.	12	0	0			
Sundry disbursements by the Treasurer	28	3	1			
Sundry payments out of Turnor Fund	0	13	6			
Deductions on country cheques	0	1	2			
Mrs. Jackson's annuity, half-year	4	6	8			
				131	18	11
India Hill Observatory, *contra*				1000	0	0
Balance at Banker's				171	9	1
				£2120	0	2

Assets and present property of the Society, Feb. 8, 1862:—

				£	s.	d.
Balance at Banker's				171	9	1
1 contribution of 4 years' standing	8	8	0			
8 ——— of 3 ditto	50	8	0			
13 ——— of 2 ditto	54	12	0			
33 ——— of 1 ditto	69	6	0			
				182	14	0
Due for publications of the Society				2	2	0
£3800 new 3 per Cents. (including Mrs. Jackson's gift).						
£2100 Consols (including the Lee Fund).						
Unsold publications of the Society.						
Various astronomical instruments, books, prints, &c.						
Balance of Turnor Fund (included in Treasurer's account) ...				59	19	10

Stock of volumes of the *Memoirs*:—

Vol.	Total.	Vol.	Total.	Vol.	Total.
I. Part 1	26	IX.	188	XXI. Part 1 (separate).	204
I. Part 2	68	X.	200	XXI. Part 2 (separate).	100
II. Part 1	85	XI.	210	XXI. (together).	117
II. Part 2	50	XII.	217		
III. Part 1	106	XIII.	234	XXII.	211
III. Part 2	125	XIV.	218	XXIII.	212
IV. Part 1	121	XV.	202	XXIV.	222
IV. Part 2	134	XVI.	223	XXV.	227
V.	154	XVII.	201	XXVI.	239
VI.	174	XVIII.	206	XXVII.	494
VII.	197	XIX.	214	XXVIII.	456
VIII.	183	XX.	211	XXIX.	281

Progress and present state of the Society:—

	Compounders.	Annual Contributors.	Non-residents.	Patroness, and Honorary.	Total Fellows.	Associates.	Grand Total.
February 1861 ...	161	207	31	4	403	51	454
Since elected	5	30	...	...	...	...	...
Deceased	−4	−3	...	...	...	−2	...
Removal	2	−2	...	...	...	...	...
February 1862 ...	164	232	31	4	431	49	480

The instruments belonging to the Society are as follows:—

The *Harrison* clock,
The *Owen* portable circle,
The *Beaufoy* circle,
The *Beaufoy* transit,
The *Herschelian* 7-foot telescope,
The *Greig* universal instrument,
The *Smeaton* equatoreal,
The *Cavendish* apparatus,
The 7-foot Gregorian telescope (late Mr. Shearman's),
The Variation transit (late Mr. Shearman's),
The Universal quadrant by Abraham Sharp,
The *Fuller* theodolite,
The Standard scale,
The *Beaufoy* clock,
The *Wollaston* telescope,
The *Lee* circle.

The *Sheepshanks'* collection of instruments, viz.,—

1. 30-inch transit, by Simms, with level and two iron stands.

2. 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.

3. $4\frac{6}{10}$ achromatic telescope, about 5 feet 6 inches focal length; finder, rack motion; double-image micrometer; object-glass micrometer; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters.

4. $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

5. $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

6. $2\frac{3}{4}$ achromatic telescope, about 30 inches focus; one terrestrial and four astronomical eyepieces.

7. 2-foot navy telescope.

8. 45-inch transit instrument, with iron stand, and also Y's for fixing to stone piers; two axis levels.

9. Repeating theodolite, by Ertel, with folding tripod stand.

10. 8-inch pillar-sextant, divided on platinum, with counterpoise stand and horizon roof.

11. Portable zenith instrument, with detached micrometer and eyepiece.

12. 18-inch Borda's repeating circle, by Troughton.

13. 8-inch vertical repeating circle, with diagonal telescope, *by Troughton* and Simms.

14. A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, with extra pair of parallel plates; tripod staff; in which the telescope tube is packed; repeating table; level collimator, with micrometer eyepiece; and Troughton's levelling staff.

15. Level collimator, plain diaphragm.

16. 10-inch reflecting circle, by Troughton, with counterpoise stand; artificial horizon, with metallic roof; two tripod stands, one with table for artificial horizon.

17. Hassler's reflecting circle, by Troughton, with counterpoise stand.

18. 6-inch reflecting circle, by Troughton, with two counterpoise stands, one with artificial horizon.

19. 5-inch reflecting circle, by Lenoir.

20. Reflecting circle, by Jecker, of Paris.

21. Box sextant and 3-inch plane artificial horizon.

22. Prismatic compass.

23. Mountain barometer.

24. Prismatic compass.

25. 5-inch compass.

26. Dipping needle.

27. Intensity needle.

28. Ditto ditto.

29. Box of magnetic apparatus.

30. Hassler's reflecting circle, with artificial horizon roof.

31. Box sextant and $2\frac{1}{4}$-inch glass plane artificial horizon.

32. Plane speculum artificial horizon and stand.

33. $2\frac{1}{2}$-inch circular level horizon, by Dollond.

34. Artificial horizon roof and trough.

35. Set of drawing instruments, consisting of 6-inch circular protractor; common ditto; 2-foot plotting scale; two beam compasses and small T square.

36. A pentagraph.

37. A noddy.

38. A small Galilean telescope, with the object lens of rock-crystal.

39. Six levels, various.

40. 18-inch celestial globe.

41. Varley stand for telescope.

42. Thermometer.

43. Telescope.

These are now in the apartments of the Society, with the exception of the following, which are lent, during the pleasure of the Council, to the several parties under mentioned, viz.:—

The *Wollaston* telescope, to Mr. Rees.
The *Lee* circle, to Mr. Burr.
The *Beaufoy* clock, to Dr. Booth.

The *Sheepshanks* instrument,		No. 1, to Mr. Lassell.
Ditto	ditto	No. 2, to Mr. De La Rue.
Ditto	ditto	No. 3, to Rev. C. Pritchard.
Ditto	ditto	No. 4, to Rev. F. Howlett.
Ditto	ditto	No. 5, to Mr. Birt.
Ditto	ditto	No. 6, to Rev. J. Cape.
Ditto	ditto	No. 8, to Prof. Wheatstone.
Ditto	ditto	No. 10, to Rev. C. Pritchard.
Ditto	ditto	No. 19, to Mr. Dayman.
Ditto	ditto	No. 23, to Mr. Spottiswoode.
Ditto	ditto	No. 25, to Mr. Dayman.
Ditto	ditto	No. 41, to Rev. C. Pritchard.

The double-image micrometer, to Mr. Hodgson.
The 6-inch circular protractor, to Mr. Birt.

Nothing definite has yet been ascertained respecting the other *Beaufoy* clock, the two invariable pendulums, and the quadrant (said to have been *Lacaille's*), reported for many years past as being in the possession of the Royal Society.

The Fellows are aware that the Council intend this day to propose, at a Special General Meeting, that the name of Miss Anne Sheepshanks be added to the list of Honorary Members. The splendid present of instruments made by this lady to the Society, and the large endowment by which she has perpetuated the name of her brother and his astronomical pursuits in his own university, most properly call for such acknowledgment as a Society devoted to Astronomy can give. So much might be said in any similar case. But when it is remembered that the brother whose memory is thus affectionately preserved was one of the best friends this Society ever had, equalled only by Francis Baily in the amount of time and labour which he bestowed upon it, and the untiring zeal with which he served it, the Council feel, and are sure the Society at large will also feel, that the duty of acknowledgment will be performed with greater pleasure in that it again connects us with the name of Sheepshanks.

The Council have to announce the receipt of a handsome reversionary gift. Mrs. Hannah Jackson has made over 300*l.* stock, reserving the dividends during her life, for the promotion of Astronomy by rewards to be given in the name of "Hannah Jackson, *née* Gwilt." The conditions, including some slight modifications to which Mrs. Jackson at once consented on the suggestion of the Council, are as follows. When the endowment takes effect, the accumulations of income, for any term not exceeding seven years, are, at the discretion of the Council, to be from time to time given in the form of a medal, or of money, or both, to the writer of any astronomical work or memoir, the inventor or improver of any astronomical

instrument, the discoverer of any new heavenly body, or the promoter in any other way of the science of Astronomy. The Council invite the Fellows to return thanks to Mrs. Jackson, not only for this very munificent gift, but for the judgment shown in allowing the mode of employment to be unfettered by any restrictions which might possibly diminish its utility.

The Council have awarded the Gold Medal to Mr. Warren De La Rue, for his astronomical researches, and especially for his application of Photography. The President will, in the usual way, explain the grounds of this award in detail: but the Council cannot help remarking that this public recognition of the success of chemical delineation of celestial objects may be an important date in the history of Astronomy. No discovery of our day affords a more hopeful field of anticipation than that of photography, which seems destined to take that part in the astronomy of visual phenomena which graduated instruments have taken in the astronomy of motions and positions.

The volume of *Memoirs* will shortly appear. It contains two papers only, these are, first, a Memoir On the Lunar Theory, by Sir J. W. Lubbock, Bart., of which an abstract was published in the *Monthly Notices*, January 1861. The memoir relates chiefly to the comparison and discussion of the numerical values of the coefficients of the several inequalities as given by M. Plana and M. de Pontécoulant, and in the American Tables, Washington, 1853; but it contains also theoretical investigations in relation to the acceleration and to certain long inequalities. Secondly, Observations on Donati's Comet—Sketches and Notes by Messrs. Lassell, Dawes, and Webb, Prof. Challis, the Astronomer Royal, and Mr. De La Rue. The paper is drawn up by Mr. Carrington. It is illustrated by eight plates.

Pursuant to the Report of a Committee on Income and Expenditure, it has been arranged that the ballot for printing of the papers intended for the *Memoirs* is to be deferred until the Council Meeting in June in each year, when a scheme of the whole volume for the year is to be submitted to the Council. The final decision upon papers provisionally approved of for the *Memoirs* is by this regulation deferred until the June Meeting.

The Council have thought it in the interest of the Society to prepare an Index of the *Memoirs*, and to offer sets for sale at a considerably reduced price. The scarcity of parts of the two first volumes has necessitated a considerable difference in the price of complete sets, and sets wanting vols. 1 and 2. The sales have not been very numerous at present, but (in whatever number effected), they tend to diminish the dead

stock, to disseminate the writings and conclusions of astronomers, and thereby directly to promote the objects of the Society, assist its funds, and increase the number of those interested in the subject.

It will hardly be necessary to inform the Meeting that the Council thought it their duty to present an Address of heartfelt condolence to Her Majesty, the Patroness of the Society, on the lamented death of the Prince Consort. Our history has never offered an occasion of the kind in which such addresses have been so thoroughly real and genuine. The country has felt for the Queen as if she had been a member of every family in the kingdom; and every useful institution mourns the loss of a real friend in the good and able Prince Albert.

The Society has to regret the loss by death of George Bishop, Esq.; Sir W. Cubitt; T. F. Ellis, Esq.; Dr. Fitton; T. Forster, Esq.; Sir W. K. Murray; General Sir Charles Pasley; W. Wilson, Esq.; M. Daussy; and M. Biot.

George Bishop was born at Leicester, August 21, 1785. From the age of eighteen he lived in London, employed in the well-known business to which he eventually succeeded. By this he added to his patrimony and became very wealthy, as do many others who well deserve the praise of serving their country in the way which they choose of serving themselves. But Mr. Bishop had also a strong love of science, and an earnest but very quiet desire of making his tastes useful, and investing some of his money in a way which would produce a higher return than can be measured by per-centage. Astronomy was a particular object of interest to him, and to obtain knowledge of it he cultivated mathematics to a greater extent than would have been supposed likely. When nearly fifty years of age, at the time when the firm establishment of his business made him feel a right to relaxation, he made a very serious study of mathematics, and mastered enough of the *Mécanique Céleste* to obtain a perfect idea of the nature of the great problems of astronomy. His conversation never gave any idea of his knowledge in this and other matters: he listened more than he talked, and was not communicative about himself or his plans.

He had always had a great wish to possess an Observatory, but never had the opportunity until he removed his residence to South Villa, in the Regent's Park. The Observatory was erected in 1836. Mr. Bishop was from the beginning well aware that by far the most important part of an astronomical instrument is the astronomer. This is the foundation of the true theory of an instrument; and the Chaldean shepherd, with no lens except that of the eye, added more to

the knowledge of the heavens than all the unused telescopes put together. Mr. Bishop, knowing that his own leisure would never suffice to work an observatory, determined that what he could not do others should. From the beginning this was his firm resolution. It was often expressed to the writer of this memoir, who especially remembers one occasion, when both were standing on the spot now occupied by the Observatory, after walking over the grounds to look for a site. "I am determined," said Mr. Bishop, "that this Observatory shall *do something*." The known solar system at that time consisted of eleven planets. Little did either party to the conversation think that the duplication of this number was part of the reward in store for Mr. Bishop's energetic and single-minded resolution to be of use.

Every particular relating to the Observatory will be found in Mr. Bishop's publication, *Astronomical Observations during the years* 1839–51. It is not necessary for us here to describe Mr. Hind's ten planets, that of Mr. Marth, the star in *Ophiuchus*, the variable stars, the new nebulæ, the valuable double-star observations commenced by Mr. Dawes, &c. The ecliptic charts must be mentioned: seventeen are engraved, and it is hoped that the difficulties in the way of the completion are now overcome.

The South Villa Observatory is connected with a succession of excellent astronomers. We need only mention the names of Mr. Dawes and Mr. Hind. Since his appointment to the *Nautical Almanac*, Mr. Hind has taken a general superintendence, the actual observers being in succession Mr. Norman Pogson, Dr. Vogel, Mr. Marth, and Mr. Talmage. Mr. Pogson commenced in this Observatory the career which has produced much and promises more: and this was always a source of high gratification to Mr. Bishop.

Mr. Bishop was elected Fellow of this Society in 1830. He was successively Secretary, Treasurer, and President. It will always be matter of regret that he was never once able to take the chair in the last capacity: the final prostration of strength which accompanied—we may almost say, constituted—his last illness, was nearly simultaneous with his election as President in February 1857. He continued in a state of fluctuating debility, without any loss of mind, until June 14, 1861, when he died without pain.

We cannot here undertake to dwell at length upon the characteristics of this good friend of our Society, and most active, though quiet, promoter of its cause. Those who were on terms of intimacy with him will never forget the excellencies of his private character. Our concern is with the manner in which he encouraged and promoted Astronomy. In 1848, speaking on the award of our Astronomical testimonials, Sir J. Herschel observed that "it does not fall to the lot of every private observatory to have added two planets to our

list." This was said at a time when the career of discovery of small planets was in its infancy. We may note that on the first opening of this path the energies of the South Villa Observatory were turned at once upon it; and the success which followed was a very great stimulus to the exertions of others. We have much satisfaction in adding that this institution is not to become extinct. It is the intention of Mr. George Bishop the younger to remove the instruments and the dome to his residence at Twickenham, and to continue the course of observation so brilliantly commenced in the Regent's Park.

Sir WILLIAM CUBITT was born at Dilham, in Norfolk, in 1785. As an engineer, his career will be recorded in other publications. He became a member of our Society, as other engineers have done, attracted towards astronomy by its connexion with mechanical adaptation. He was a good transit observer, and he constructed Mr. Cooper's telescope tube. The inventor of the self-acting windmill-sail, the constructor of the great landing-stage at Liverpool, the executive engineer of the railway from London to Dover, the superintendent of the construction of the Crystal Palace of 1851, is not likely to be forgotten in his line. The host of minor undertakings which he directed is past all enumeration; and it must not be forgotten that he deserves the thanks of every honest man as the inventor of the treadmill.

Sir William Cubitt was the son of a miller, and became a millwright after being apprenticed to a joiner. He has, accordingly, been represented as having risen in the face of every disadvantage; but this was not the fact, though easily credible of such a man. The apprenticeship was probably considered as an additional introduction to his intended career, he having already had much experience of the special working of a mill in his father's business.

Mr. Bidder states that his success was in a great degree to be ascribed to the soundness of his early mechanical experience, which he never failed to impress upon all the younger members of his profession. He died in October last.

THOMAS FLOWER ELLIS was born December 5, 1796, and died April 5, 1861. He was educated at Cambridge, where his career in classics was distinguished, and he gained a fellowship at Trinity College in 1819, which he vacated by marriage in 1820. He was called to the bar in 1824, and continued in practice till his death, being for many years one of the reporters of the Court of Queen's Bench. In 1839 he was made Recorder of Leeds, and Attorney-General for the Duchy of Lancaster. He was one of our earliest members, having been elected in May, 1820. He was elected to the Royal Society in 1847, and was also a member of the Cam-

bridge Philosophical Society, the Philological Society, &c. On the Northern Circuit he made the acquaintance of the late Lord Macaulay, with whom he contracted a warm friendship. Lord Macaulay made him his executor, and in this capacity he edited the posthumous works of his distinguished friend.

Mr. Ellis was one of a class which is more numerous in England than in any other country—the class of persons who carry into professional life what would on the Continent be a *professorial* knowledge of literature or science, and make it the duty of their leisure to apply it to the benefit of others. He was for many years a hardworking member of the Society for the Diffusion of Useful Knowledge, which he took up from the commencement with the feeling of personal responsibility for what was published by that corporation. In various other ways he was steadily applying himself to utilities of the same kind. In his career at the bar he also occupied a post of importance, to which no public recognition is attached. The reporters of our courts of law, on whom the judges mainly depend, not only for precedents, but for the arguments on which they are founded, are themselves unknown to the courts whose proceedings they record, and belong rather to the publishers who undertake the volumes of reports than to the great system which lives and grows by their publications. But we believe we may say that the judges themselves are not more free from all impeachment than their reporters.

Mr. Ellis was attached both to literature and to science, but his tastes were of a very mathematical cast. His principle, throughout life, was the promotion of knowledge; and in this field he worked from the time when he joined our Society in its infancy to the end of his useful life. None but those who were either his friends or colleagues were cognisant of his career.

The Council regret that his pursuits of necessity severed him from active participation in our meetings of the Society; and they feel that they have lost a member whose course of life was a continual credit to every Society whose designation he attached to his name, and to ours from its very commencement.

The Council regret that they cannot procure an account of Dr. Fitton. This zealous geologist had been a Fellow of the Society since 1825, and, though not immediately connected with astronomy, often attended our meetings. Almost to the last he was seen among us on occasions when important subjects were agitated.

Thomas Ignatius Maria Forster was born in Threadneedle Street, November 9, 1789. He was of an ancient Border family, which was confiscated in the Rebellion of 1715.

His father, who was in business, was a zealous botanist, and published a *Flora Tunbrigiensis* in 1812. His uncle, B. Meggot Forster, was known by many papers on physics and botany; and another uncle, Edward, a partner in the house of Lubbock and Co., was also known as a botanist. Thomas Forster has left an account of his own life, published in French at Brussels in 1836: he speaks in detail of the botanical tendency of his family, and says that as soon as the ledger was shut the *hortus siccus* was open. He himself began, at the age of sixteen, a *Liber Rerum Naturalium*, and a *Journal of the Weather*, which he continued till his death.

At the age of seventeen he became acquainted with Spurzheim, whose system he adopted. It was Mr. Forster who gave the name of *Phrenology* to what was till then called *Craniology*, in a tract entitled *Sketch of the Phrenology of Gall and Spurzheim*, London, 8vo, 1816. Spurzheim told him that he had a head well organised for science, but with too much *ideality* to allow it to be used with effect.

Mr. Forster was a member of Corpus Christi College, Cambridge, and took the degree of M.B. in 1819. In 1817 he married a daughter of Colonel Beaufoy, a well-known Fellow of this Society, which he himself joined in 1824. He led a wandering life till about 1834, when he settled in Belgium, where he remained till his death, either at Brussels or at Bruges. He spoke and wrote various languages with facility. His detached works are beyond all enumeration: most of them are on atmospherical and meteorological phenomena, not forgetting an account of a balloon-ascent which he made in 1831. One of his earliest works, *On the Brumal Retreat of the Swallows*, published under the name of Philocheledon, reached a sixth edition in 1817.

When M. Quetelet showed him some accounts of the shooting stars of August 10, he was greatly astonished; but a few days afterwards he pointed out to M. Quetelet that he had long before announced the phenomenon as periodic, in his own Atmospherical Calendar, which he had entirely forgotten. This was made known at the time.

Mr. Forster was an upright and amiable man, with many peculiarities of mind and habit; a scholar and a linguist of very wide reading, and zealously attached to observation of natural phenomena.

Sir WILLIAM KEITH MURRAY, Bart., was born at Ochtertyre, in Perthshire, on the 19th of July, 1801. Educated at Harrow and Sandhurst, he entered the army in 1821, joining the 42d Highlanders, where he attained the rank of captain. In 1830 he left that celebrated corps, and joined the Perthshire Militia as lieutenant-colonel. More recently still, on the rise of the Volunteer movement, he was appointed colonel of the

Perthshire Rifle Volunteers, and engaged both enthusiastically and laboriously in those new duties until within a few weeks of his death.

At Sandhurst he had been distinguished for proficiency in military sketching and outline drawing—a talent which he employed abundantly and to good purpose in after-life—publishing, in 1832, a volume of his original sketches of Scottish and Highland scenery, taken in that manner.

He was also an accomplished musician, and was most skilful at the turning-lathe. His taste for telescopic observing only manifested itself later in life; but having, in 1850, erected at Stonehaven a small equatoreal-room of 15 feet in diameter, on the plan described by Sir John Herschel in his work on the *Southern Heavens as observed at the Cape of Good Hope*, he commenced a larger Observatory in 1853, at his family seat of Ochtertyre, and published a description of it, with plates, in 1859.

The most noteworthy particular of the building was, perhaps, the mounting of the great dome, 18 feet in diameter, on the rims of large (2-foot) wheels, the axes of which rested on *fixed* bearings in the wall; proving that this was both an economical and effective practical method of securing an easily revolving roof. Of the instruments, the chief one was an equatoreally-mounted telescope, of 9 inches aperture, by Cooke and Sons, of York. The optical qualities of this object-glass he was most unwearied in testing on every known difficult object in the heavens, month after month, and year after year, until he had put beyond all doubt the quality of Mr. Cooke's optical work.

With all this energy and determination of purpose, Sir William preserved remarkable modesty amongst learned men, and ever showed the most kind attention to the wishes of his neighbours and the educational interests of his tenantry and the inhabitants of the neighbouring towns and villages. Hence his own advance in science was much impeded by the time he devoted to others; and an interesting specialty of his Observatory always was, the large number of very respectable telescopes which he had fitted up for the use of all who chose to profit by them. His popular lectures in the neighbourhood were frequent and well attended, illustrated generally with great skill by his own mechanical or optical contrivances. He was, in short, never weary of well-doing according to his position in life, and was one of those men occasionally met with in the world who are gifted with almost superhuman activity, seldom requiring more than three or four hours' sleep, and busily engaged in working or superintending the work of others through the remainder of the day.

Sir William was twice married—first, in 1833, to the only daughter of Sir Alexander Keith, of Ravelstone and Dunottar, in whose right he assumed the name of Keith; and secondly,

on the death of this lady, after having had by her eight sons and three daughters, to Lady Adelaide Hastings, youngest daughter of the first Marquis of Hastings. Lady Adelaide died in December, 1859; and Sir William Keith Murray, who never fully recovered from the effect of her loss, was carried off by an attack of typhus fever in October 1861.

General Sir CHARLES WILLIAM PASLEY, K.C.B. and D.C.L., died at his house at Norfolk Crescent, Hyde Park, on the 19th of last April, in his eighty-first year, having been a member of this Society during twenty-seven years. He was also a Fellow of the Royal, the Geological, the Geographical, and the Statistical Societies, being everywhere active in the cause of practical science.

This distinguished officer was born at Eskdale-Muir, Dumfries, on the 8th of September, 1780, and received the rudiments of his education in the High School at Edinburgh. He was appointed a second lieutenant in the Royal Artillery in his seventeenth year, from whence he was transferred to the Royal Engineers, where he became a captain in 1807, a lieutenant-colonel in 1814, and a colonel in 1831. He was promoted to the rank of major-general in 1840, lieutenant-general in 1851, and general in 1860.

The early years of Pasley's career in the army were marked with activity and incident. In 1799 he was stationed in Minorca, where he remained three years, and was then sent to Malta, in which island he rendered himself very serviceable, insomuch that General Villettes selected him to go with a confidential communication to Admiral Lord Nelson: and here his professional talent was evinced in a scheme for protecting the exposed heights of Corradino by means of four strongly fortified trapezium redoubts, the plan of which is still preserved among the muniments of that island. He served at the defence of Gaeta in 1806, under the Prince of Hesse Philipstadt; at the battle of Maida with Sir John Stuart; and at the siege of Copenhagen, under Lord Cathcart, in 1807. In the following year he was sent to the Peninsula, where he was in several sharp skirmishes, as extra aide-de-camp to Sir David Baird; and at the battle of Corunna he acted in the same capacity to the commander-in-chief, Sir John Moore. Captain Pasley next served in Walcheren, where, on the 9th of August, 1809, he received a bayonet-wound through the thigh, and a musket-shot which injured the spine, in leading a storming party to a French advanced work on the dyke in front of the citadel of Flushing.

In these incessant services it was the good fortune of Captain Pasley to win the approbation of all the generals under whom he was placed, and by all of whom he was employed on special duties and trusty missions. But his personal activity for the field having been restricted in con-

sequence of the severe wounds which he had received, Lord Mulgrave appointed him Director of the Royal Engineer Establishment for Field Instruction at Chatham, which important post he ably held from the year 1812 till the end of 1841. Nor in this Society should it be forgotten that he there founded an efficient Observatory for initiating young officers into practical astronomy, and which was also supplied with such portable instruments as a military engineer ought to be acquainted with. Shortly after quitting Chatham, he was nominated an Inspector of Railroads.

Meanwhile Colonel Pasley had directed his energetic mind to the removal of wrecks under water by means of voltaic explosions of gunpowder; and in 1838 he blew to pieces the sunken hulls of two merchantmen in Gravesend Reach, so that their fragments were easily weighed. So fortunate an operation led to the gigantic enterprise of clearing the road of Spithead from that well-known incumbrance, the Royal George, a first-rate man-of-war, which had been lying at the bottom more than half a century. This arduous undertaking was most successfully executed; and by the public sale of the guns, copper, timber, and *débris* which were fished up, this very important anchorage was cleared without any expense to the country.

We must mention, in conclusion, that Sir Charles Pasley was an author of considerable note. In 1810, a time of great alarm, he published a very remarkable volume on the *Military Policy of Great Britain.* It was much read, and is a valuable book, whether considered as to its enlarged political views, its fair and candid reasonings, or its spirited patriotism—a meed which is granted even by those who cannot concur in all its doctrines. He also wrote *A Course of Elementary Fortification,* in 2 vols.; *Practical Geometry and Plan-Drawing; Improvement of English Weights and Measures;* and *Rules for undertaking the Operations of a Siege.*

For more than half his life Sir C. Pasley strongly advocated the introduction of decimal coins, weights, and measures—never holding with those who would introduce the French units into this country, but desiring the complete introduction of the decimal principle of division. Of this proposal he was one of the earliest supporters.

William Wilson was born in Spitalfields in the year 1768. His career affords a striking example of the effect of self-culture in overcoming the disadvantages of a very limited education and want of position. When a mere child, he was employed by a weaver as what was then called a draw-boy. He was afterwards apprenticed to a chair-maker, and followed that calling for a time; but having a strong natural bias towards scientific pursuits, he devoted his leisure to the acquirement of that kind of knowledge, and by industry and

perseverance succeeded in raising himself far above his original position.

In 1796 he joined the Mathematical Society of Spitalfields, a Society which was established in 1717 for the purpose of mutual instruction in the mathematics and the promotion of general science. Here he soon distinguished himself, for the Society having, in 1795, removed to convenient premises in Crispin Street, it was shortly after proposed that a course of elementary lectures on the various branches of natural and experimental philosophy should be annually delivered, to which the public should be admitted at moderate cost. Mr. Wilson, in co-operation with Mr. Joseph Stevens, the Engineer to the East London Waterworks, rendered most effective assistance in carrying out this scheme. The first of these courses was delivered in 1798, and they were continued for nearly thirty years, Mr. Wilson taking an active part in their delivery during the whole of that time.

He was for many years Assistant to Mr. William Allen, Lecturer on Chemistry at Guy's Hospital. When, in 1825, his services were no longer required by that gentleman, having but slender means of support, the Committee of the Mathematical Society, in consideration of the eminent services rendered by him to the Society for so many years, gave him the entire benefit of the course of lectures for that season. Mr. Wilson, consequently, delivered the whole course, being a series extending over about twenty consecutive weeks; the writer of this notice officiating as his Assistant.

He was afterwards employed as Superintendent of the workmen of the Gasworks at Haggerstone; and when, after many years' services, the infirmities of age compelled him to retire from active business, a competent annuity from that Company afforded him adequate support for the remainder of his life.

Although entirely self-taught, Mr. Wilson's attainments were of no common order. He was not only well versed in the mathematical principles of natural and experimental philosophy, in illustration of which he, in conjunction with his friend Mr. Stevens, constructed a great variety of ingenious apparatus, admirably adapted to explain and demonstrate those principles to an audience, but he was an excellent chemist, as may be seen by a reference to an important series of experiments on the explosive compound of chlorine and nitrogen, then newly discovered, which in the year 1813 he undertook, in conjunction with Messrs. R. Porrett and Rupert Kirk, an account of which is published in the thirty-fourth volume of Nicholson's *Journal of Natural Philosophy, Chemistry, and the Arts*. He was also a botanist and mineralogist, and formed a large collection of objects for the microscope, mounted with his own hands. In short, there was scarcely any portion of the science of his day to which he had not applied himself

with success. He was much and deservedly respected by the members of the Mathematical Society, as he was at all times ready to communicate any information in his power to an inquirer, and endeavoured to render such information as intelligible as possible. For many years he was the senior member of that Society, but never filled the office of President. He became a Fellow of this Society when the junction of the Mathematical Society with it took place in 1845. He died in January, 1861, in his ninety-third year.

PIERRE DAUSSY was born at Paris, October 8, 1792; his father was what he afterwards became, *Ingénieur Hydrographe.* While engaged in the school of hydrography, he studied astronomy in theory and practice at the observatory of the *Ecole Militaire,* under Burckhardt. From 1810 to 1814 his time was mostly devoted to astronomy. His occultations were published in Zach's *Correspondance.* He calculated the orbits of the second comets of 1814 and of 1737. In 1813 he presented to the Institute a memoir on the perturbations of *Vesta,* which gained the Lalande medal. A second and more extensive memoir on the same subject was published by the Bureau des Longitudes in the *Connaissance des Temps* for 1818; and tables founded on the elements therein contained were published in the same work for 1820.

From 1816 to 1826 Daussy was employed in triangulations which extended along the coast from Brest to Bayonne, thus joining the whole coast to the great triangulation. Puissant spoke in high terms of the execution of this work, and states that its agreements with the larger triangulation show the two to be parts of one whole. The *précis* of the whole was published in 1829, at the end of the *Exposé des Travaux, &c.,* of M. Beautems-Beaupré. In 1829 he was employed in the connexion of the Channel Islands with the coast near St. Malo, at which time he also paid special attention to the local tides, on which he published two memoirs in the *Connaissance des Temps* for 1834 and 1838. His researches led him to the discovery, since verified by others, of the variation of the mean level of the sea with the height of the barometer.

It is not our place to follow Daussy through the long train of purely geographical labours by which he bore his part, and no small one, in raising the French school of hydrography to a high pitch of reputation and of utility to the whole world. An excellent account of the whole, though short, will be found in the notice by M. de la Roquette, inserted in the 20th volume (4th series) of the *Bulletin de la Société de Géographie.* He died September 5, 1861. His personal character was of the highest, and he was respected accordingly. Of the various marks of consideration which he received, the one which is now best worth noting is, that he was President of the Geographical Society of Paris. He was of the Institute of the Legion of

Honour, Astronome Adjoint of the Bureau des Longitudes, &c.

Just as this Report was ready for the Meeting news arrived of the death of Jean Baptist Biot, the oldest Associate of the Society, and the last of the celebrated *savans* of what he himself called the first edition of the French Republic. M. Biot would have been 88 years old if he had lived two months longer; and to the last he was actively employed. In November, 1861, he completed an elaborate survey of Chinese Astronomy for the *Journal des Savants*. Biot was alive in the time of D'Alembert and Voltaire, with either of whom, as a child, he might have talked; thus, better than by dates, we gain a notion of the long period through which he lived. It is necessary to defer until next year all detail of the labours of this distinguished cultivator both of science and letters.

In the ordinary operations of the Royal Observatory, Greenwich, very few changes have been introduced during the year 1861. The observations are of precisely the same character as before, and the reductions have been made to keep pace with the observations. The volume for 1860 has been very nearly passed through the press. The formation of a catalogue, embracing the star-observations from 1854 to 1860, is vigorously progressing.

The Great Equatoreal has been principally employed in observations of *Jupiter* and *Saturn*. A connected series of drawings of these planets has been made. The instrument has also been employed in observations of Comet II., 1861.

It has been known for several years that interruptions of communications by the Galvanic Telegraph occur, from time to time, produced by spontaneous galvanic currents passing through wires whose extremities are connected with the earth. Arrangements have now been made, and the works are in progress, for the self-registering of these earth-currents at the Royal Observatory. A grant for this purpose has been made by the Admiralty, and the arrangements have been much facilitated by the liberality of the Directors of the South-Eastern Railway, along whose lines the wires are to be carried, and by assistance rendered, in several ways, by their indefatigable Superintendent of Telegraphs, C. V. Walker, Esq.

The observations of the Royal Observatory, Edinburgh, are printed to the end of 1859, and in the Meridian Department are being continued as usual, or, it is hoped, with more than usual accuracy, in consequence of the successful completion during the last year of a long series of experiments which have been carried on during many years with the view

of removing some acknowledged defects from the sidereal clock—a most vital part of a meridian observatory.

The Astronomer's attention had long been called to the subject on account of the double evils,—1st, of minute changes of rate, dependent on small and rapid variations of temperature; and, 2d, of inaudibility of the seconds' ticks in the high winds of an exposed hill-top. Each of these difficulties has now been overcome with as much completeness as if the other had had no existence, although at first they appeared to require antagonistic applications; and the result is, that the *time-keeping* department of the old transit-clock has been confided, pure and simple, to a clock (that which was presented to the Observatory by the late Sir Thomas Brisbane) enclosed, at a distance from the transit-instrument in a closet, in a covered part of the Observatory, tending to equal temperature (in the manner of the position of the Normal Clock at the central Observatory of Pulkova); but the *observing* department of the same old transit-clock is now taken up by a different clock altogether, and one the whole mechanical arrangements of which are devoted to enabling the seconds to be seen and heard by the observer at both the transit-instrument and mural circle, as easily and powerfully as possible; while its rate of going is taken electrical charge of by the other, or the time-keeping clock in the dark closet. By means of a small tilt-hammer, which strikes at every second on the outside of the case of the observing-clock, the audibility of the seconds tick seems carried to the highest desirable point; and by Mr. Jones' (of Chester) method of electric controlling, the required action of galvanism has been attained with invariable certainty, and at the smallest current expense for electricity that can well be conceived, as is judged after the experience of about nine months.

Almost simultaneously with the improvement of the sidereal-clock system of the Observatory, a considerable extension of its duties took place with regard to its mean-time arrangements; for the public of Edinburgh, no longer content with a visible signal of the true time daily, demanded an audible signal of it as well, in the shape of a cannon fired from the Castle of Edinburgh by electric influence from the Royal Observatory, Edinburgh; and having raised voluntary subscriptions to pay all expenses, except those incurred at the Observatory, they procured the necessary authorisation from Government to carry out the work. The mechanical arrangements have been carried out with much precision.

Amongst the extra duties of the Observatory, the reduction, for the Registrar-General of Births, Deaths, &c. in Scotland, of meteorological observations from fifty-five meteorological stations in the North, still goes on, and occupies much time.

During the last severe winter and spring the health of

the Astronomer and Assistants suffered so much, that the Board of Visitors was induced, during the summer, to take up the important subject of suitable accommodation for the observers, but were not able to come to any practical result at present. The official house of the Astronomer is not only at a considerable horizontal distance from the Observatory, but at a lower level by so much as two hundred and forty feet vertical: the labour of such a journey, by both night and day, and through all seasons of the year, is enough to sap the health of any one, especially when it is remembered to engage in what sort of sedentary computing occupation the chief part of the ascents are made.

At the Radcliffe Observatory, Oxford, the arrears of the printing of the Observations have been lessened by the publication of the nineteenth volume of the *Radcliffe Observations*, and the reductions have been carried on with sufficient vigour to ensure the speedy publication of another volume, containing the Observations of 1859 and 1860. The printing of the Observations of 1859 is nearly completed.

Throughout the year 1861 the meridian observations were made as before with the transit instrument and meridian circle, the chief subject of observation being the completion of Mr. Johnson's Catalogue of Remarkable Objects. In the summer, however, of 1861, there was purchased, with the consent of the Radcliffe Trustees, the transit circle belonging to Mr. Carrington, which had been used with such good effect by him at Red Hill. Mr. Main himself superintended the mounting of it at Oxford on the same piers that were used at Red Hill, and the whole was successfully accomplished considerably before the end of the year. Actual observations were commenced with it at the beginning of the present year, the chief subject of observation being the stars visible there between the fifth and the seventh magnitudes. In addition, the Sun is observed, and the Moon till opposition, together with some of the large planets, and such of the minor planets as can be seen with the telescope, of which the diameter is 5 inches.

With the heliometer Mr. Main has been engaged with the observation of a catalogue of double stars, and has already observed considerably more than one hundred. *Jupiter* and *Venus* have been also well measured. A long series of observations of the Great Comet of 1861 was also made, and the results have been communicated to the Society, and are printed in the December Number of the *Monthly Notices*.

The Photographic Meteorology has been well kept up as in former years, but with a diminished staff since August last. The only assistants employed at the Observatory since that time are Mr. Quirling and Mr. Lucas; and it is due to the energy and zeal of those gentlemen to state, that so large an

amount of work could not be done without the most incessant exertions on their part. The Observatory has, in addition, the advantage of Mr. Luff's services as a computer; and these have been most valuable and useful.

It may be considered that the prospects of the Radcliffe Observatory for the future are encouraging. It is now adequately supplied with excellent modern instruments, which are employed effectively for useful purposes; and, though the staff of assistants is small, it will probably be found, by economy of labour, adequate to the carrying out the views of the Directors, and to the sustaining of the past reputation of the Observatory. We are sure, moreover, the Society will duly appreciate the enlightened liberality of the Trustees, in purchasing without hesitation the Carrington Transit-Circle, as soon as it was explained to them that the demands of science at the present time required the establishment of an instrument of that class.

The Observatory of Cambridge is at this moment in the state which necessarily arises from a change of superintendence, and, to some extent, of system. Professor Challis discontinued residence at Michaelmas, and Professor Adams is on the point of commencing residence, having been in charge since Mr. Challis left. The interval has been employed in making some alterations which would, perhaps, hardly be thought worthy of mention, but both gentlemen speak so strongly of the improvement effected, that notice may be taken of them in illustration of the importance of little aids to convenience. The calculating-room had been intended to receive an instrument, and the slits in the sides and roof gave it that tendency to equality of temperature with the outer air which promotes observation more than calculation. The Superintendant's private room was also a thoroughfare.

By aid from the Sheepshanks' fund, Mr. Challis completed the reduction of all the meridian observations made under his care, and also made some progress in the final reduction of the equatoreal observations. The printing is about to be commenced. A long and good series of the conspicuous comet of July last was carried to nearly the end of the year: the publication awaits the determination of some of the comparison stars. The transit of *Mercury* and the Solar Eclipse were hidden by clouds.

Mr. Adams, without having settled details of plan, intends to take up some definite class of observations, of not too extensive a character for his staff, and to discuss the results: without binding himself to engage largely in the routine observations which are sufficiently attended to at Greenwich. This plan he takes to be most fitted to create and keep up in the University a spirit of astronomical inquiry, one of the chief objects for which the Observatory was founded.

The University Syndicate, after paying a well-merited compliment to the long and able services of Mr. Challis, rejoice that the Observatory has still the advantage of his official connexion with it as Plumian Professor. In this the Society will join; and the astronomical world will look forward to good results from the union of the efforts of Mr. Adams and Mr. Challis, with the power of obtaining subordinate labour which the Sheepshanks' fund is likely to add.

When the Astronomer is far removed from the society of his scientific colleagues, events of his domestic life may become legitimate objects of mention in our Report, in all cases of which the Fellows would desire to convey the expression of sympathy. The zealous Astronomer of the Cape of Good Hope will feel assured of the sincerity with which the Society expresses its regret at the death of Lady Maclear.

Encke's Comet was found at the Cape early in December. To use Sir T. Maclear's words, "it comes up sharp to the predicted orbit." It was, however, too faint for good observation when the last letters were received.

The extensive alterations and improvements at the Liverpool Observatory are now completed, and Mr. Hartnup is again at work with the Equatoreal. The new arrangements for testing and rating chronometers are much admired by all who have seen them, and fully answer Mr. Hartnup's expectations. The results of the first trial of chronometers with the new arrangements have been published in the *Horological Journal.* The new room having been found too large for the normal clock to be heard distinctly in every part, another clock has been added and successfully controlled by Mr. Jones' method, so as to produce perfect coincidence of beat with the normal clock. This new clock has a dial, twelve inches diameter, and a seconds' hand only, the minute and hour hands not being required; it is controlled with the same current which is used for working the relays in connexion with clocks in different parts of the town, and the battery power is, consequently, excessively great in comparison to the driving power. On first starting this clock, the beat, with the current on, soon fell behind that of the normal clock from one to two-tenths of a second, and remained so till the pendulum of the controlled clock was shortened, so as to make it gain a little; the coincidence was then found to be perfect, and it has required no alteration since. Mr. Hartnup states that when the escapements and pendulums of these clocks are made under the direction of the inventor and patentee, there is no danger of stopping them by reversing the current or applying it at the wrong time, as he has repeatedly tried the experiment with the small clock above named, and also with the large clocks in the town, one of which has six dials of eight feet diameter

each. The Town Hall clock, which has four dials, formerly went very irregularly, and sometimes stopped during high winds, frost, or snow; but since it has been controlled from the Observatory, the severity of the weather has neither stopped it nor interfered with the regularity of its performance.

All the public clocks belonging to the Dock Estate are now placed under the management of Mr. Hartnup, and a man is attached to the Observatory to look after them. Of all the methods which have been adopted in Liverpool for the dissemination of accurate time, the seconds' clock, which is controlled from the Observatory, appears to be the most highly appreciated by the public. This clock is placed in the office-window of the Magnetic Telegraph Company, and can be seen from the Exchange flags. On the 4th February, 1861, the Secretary of the Telegraph Company caused the number of persons to be counted, and between 6 A.M. and 5 P.M., 1860 persons compared watches or chronometers with this clock. The seconds' clock above named makes contact every minute at the sixtieth second, and a current is returned to the Observatory to show that it is correct. In addition to this, an arrangement has recently been made by the Engineer of the Magnetic Telegraph Company, at the suggestion of Mr. Hartnup, by which the return current can be passed on to London.

Attached to one of the Liverpool instruments there is a switch, which, when turned, prevents the clerk from working, and leaves the wire exclusively to the clock; so that at any time, day or night, when the wire is not wanted for ordinary work, London can receive time-signals from Liverpool every minute, and the errors arising from dependence on a single current are in this way avoided.

The meteorological work of the Observatory has, Mr. Hartnup says, been much heavier during the past year than heretofore. The Underwriters are beginning to take more interest in this department, the efficiency of which will shortly be greatly improved by the addition of a self-registering barometer of a novel construction.

Professor Grant reports that, at the Glasgow Observatory, attention is chiefly devoted to the reobservation, with the Meridian Circle, of a selection of stars in the British Association Catalogue ranging between the sixth and eighth magnitudes. It is also contemplated to include in the list of objects for observation some of the smaller stars of the Armagh Catalogue which have been found to exhibit a considerable proper motion. Negotiations are at present in progress for supplying the Observatory with an equatoreally-mounted refractor of considerable dimensions. The Town Council have finally decided upon laying down a wire between the Observatory and several of the

city clocks, with the view of having the latter controlled by the application of Jones's electro-magnetic method. In all probability a similar connexion will shortly afterwards be established between the Observatory and the time-ball which is daily dropped for the use of the shipping in the Clyde.

With respect to the proceedings of the Hartwell Observatory during the last year, since the departure for Madras of Mr. Pogson, who was observer from December 1860, little of interest to the public has been done.

Mr. Pogson is busily engaged in preparing the Hartwell and Madras Atlas of Variable Stars, at moments when not occupied by his public duties as Astronomer at Madras; and his situation in the Observatory at Hartwell has not been filled. Meanwhile the several instruments are at the disposal of Admiral Smyth and Captain Jacob.

Among other observations, Encke's Comet was picked up by Mr. S. Horton, the Assistant, on the 24th, 26th, and 30th of last November.

Mr. Lassell writes from Malta that he has succeeded in the perfectly successful erection of the 4-foot equatoreal, on a favourable site near Fort Tigné, on the north side of the Quarantine Harbour. The whole was effected without any accident, either in transmission or erection; and the mirror now in use, when its coat of varnish was dissolved and removed, came out as fine in lustre as if it had been just polished. Mr. Lassell now feels that he has such an instrument as he never had before, and he begins to be dissatisfied with his previous drawings. Some remarks on the performance of his telescope, and the discovery of a new star in the trapezium of the great nebula of *Orion*, will receive due attention at the next ordinary meeting of the Society.

Mr. Balfour Stewart, Director of the Kew Observatory, states that during the past year several experiments were made at Mr. De La Rue's request, to ascertain whether any advantage resulted by increasing the aperture of an object-glass beyond that found adequate to the production of a good sun-picture. The aperture of the heliograph was cut down by stops to 2 inches, and gradually increased to the full aperture of $3\frac{1}{4}$ inches; but it was not found that increase of aperture showed more details or gave a sharper image than with the 2-inch diaphragm. Preparations were made for photographing the transit of *Mercury* on November 11; but, unfortunately, the day proved hopelessly cloudy, and the Sun was not visible.

From November 7th to 20th, a very complete series of solar photographs were obtained, which have been placed in Mr. De La Rue's hands for measurement with his new instrument. They are thirty-six in number, and of great beauty,

showing the minute details on the Sun's disk with remarkable precision. They render evident the capabilities of the instrument, and the command of it possessed by Mr. Beckley.

Only two pictures could be obtained of the partial eclipse of December 31, in consequence of the clouded state of the sky and a thick mist which obscured the atmosphere; each of the pictures required an exposure of several seconds. With the instantaneous apparatus not the slightest trace of an impression was formed.

Since the 31st December the optical part of the heliograph has been removed from the stand and transferred to Mr. De La Rue's Observatory at Cranford, that gentleman having undertaken to register the Sun's disk by means of the Kew instrument.

At the Observatory, Cranford, a series of experiments has been made with the view of obtaining photographic pictures of the Sun's surface on a very large scale, in order to show the details of the spots and other markings with sufficient distinctness to render evident the changes which take place in them. After many trials, which at first gave very little promise of success, Mr. De La Rue succeeded in procuring pictures of the Sun on a scale of 36 inches to the Sun's diameter. The plates actually used were not more than 18 inches square, so that only a portion of the solar disk could be depicted at each operation. At the November Meeting these photographs were described, and several were distributed to the Members present; and it was stated that, by taking two views of the same sun-spot at an interval of several hours, they could be advantageously studied with the stereoscope, which rendered evident the relative positions of the several parts in regard of altitude and in other respects. In this way Mr. De La Rue had obtained a proof that the faculæ occupy the highest regions of the Sun's photosphere; the spots appearing as holes in the penumbra which inclined in some cases downwards, funnel-like, from the brighter parts of the Sun's disk; portions of faculæ could also be made out to be sailing high above over the spots and penumbræ.

Mr. De La Rue states that he has been much occupied during the past year in measuring the photographs procured of the eclipse at Rivabellosa in 1860, by means of a new measuring instrument, and that the results obtained show that photography is capable of yielding the most accurate numerical data, as well as of depicting the physical features of astronomical objects.

The tube of the Kew heliograph is now mounted on an outrigger affixed to the declination axis of his large Equatoreal, and is for the present under the charge of his photographic assistant, Mr. Reynolds.

Several drawings of Comet II. 1861, have been made, but all attempts at photographing it completely failed; not only was no impression procured with the reflector, but even with a short focus portrait-lens and an exposure of the sensitive-plate during 15 minutes, not the slightest trace of the comet could be obtained; the stars in its neighbourhood imprinting themselves perfectly.

Professor William Selwyn, of the College, Ely, has, by means of a small instrument constructed by Dallmeyer, on the plan of the Kew heliograph, procured some very good solar photographs. Unfortunately, the instrument has no position-wire, so that there was no means of determining the co-ordinates of the spots.

M. Faye communicated to the Académie des Sciences in December last, that he had succeeded in obtaining, photographically, a complete series of transit observations of the Sun, and of registering the exact moment of the production of each image by means of electro-magnetism. An assistant, in exposing the plate, at the same time brought into action the electro-magnet, but M. Faye points out that the assistant may be replaced by an automatic apparatus connected with the transit clock. In this way a plan, suggested as possible in 1849, and in part carried out by M. Liais, a French astronomer, who formed one of the Brazilian expedition to observe the total eclipse of 1858, has been finally brought to a successful issue by M. Faye.

M. Vernier of Belfont obtained six photographs of the eclipse of December 31st last; these photographs were each procured in a small fraction of a second, notwithstanding which, and also the sky being perfectly clear at the time, in four of the photographs the Sun's image is surrounded by a halo, which M. Vernier appears to consider as in some way appertaining to the Sun. No such halo surrounds the Sun's image in the Kew photographs, the negative impression of the Sun standing out on a perfectly transparent background. Most probably, therefore, the halo is due to irradiation or to over-exposure, when our atmosphere in apparent contiguity with the Sun will imprint itself.

Mr. Dallmeyer is under Mr. De La Rue's direction constructing a Heliograph, ordered by M. Otto Struve for the Russian Government: it is destined to be placed in the Observatory of Wilna. Messrs. Simms are also making one of Mr. De La Rue's measuring instruments, to be used in connexion with this heliograph.

From the attention which astronomical photography is attracting, it is likely that it will soon be adopted as one of the means of recording phenomena in some of the government Observatories, and that more especially sun-observations will

be made by it, from the circumstance that sun-pictures are obtainable with great facility and instantaneously.

Professor Kaiser, Director of the Observatory, Leyden, has intimated that a new Observatory on a grand scale has been recently completed at Leyden, and supplied with excellent instruments; although not yet in full activity, some experiments have been already made by Mr. P. T. Kaiser, son of the Director, having for their object the application of photography to astronomy. The instrument employed was the new 7-inch Munich refractor by Merz, and some lunar photographs have been taken with it, which, however, in consequence of the driving clock of the instrument not having sufficient power, are not so perfect as could be desired.

The erection of telescopes in more favourable situations than British islands afford, has received increased attention of late years, as evinced by the expeditions of Prof. Smyth to Teneriffe, and of Mr. Lassell to Malta. A proposal made about ten years ago, to erect a reflector of the largest dimensions in Australia, proved abortive from the difficulty of finding the corresponding Observer. A little later, however, another scheme was the subject of much correspondence between certain Fellows of this Society, which was principally suggested by the destruction of the Observatory at Lucknow, and the confirmed unhealthiness of Madras, and the presence at the head of the India Board of a nobleman with whom the motives of astronomical enterprise would find appreciation, and such aid as his department could afford. The social and financial disturbances caused by the Indian Mutiny, however, prevented progress at that time with any prospect of success. But, during the past year, the subject was brought definitely before the Council of the Society in the form of an offer by Capt. Jacob to provide an Equatoreal of high excellence, to transport it to a hill station near Poonah, and work it in that admirable climate at an elevation of nearly 5000 feet above the sea for three years, provided certain of the heavier incidental expenses were provided for by the exertion of the influence of the Council. The offer was accepted after consideration by a Committee, and application for a grant of public money was made to the First Lord of the Treasury, and by whom the sum required was submitted to Parliament and voted very shortly after, as the letter recently printed in the *Monthly Notices* has already shown. The required assistance being thus readily promised, it remains to state that the Council expect as the result, not a mere record of tests showing the degree of excellence of the climatic conditions obtained, but some considerable additions to the details of the physical scrutiny of celestial objects, which may induce other observers of independent position to regard a good climate of equal im-

portance with a good telescope, and to go wherever it may be necessary to find it. The success of the enterprise will depend very much on the health of Capt. Jacob, who is expected to set out very shortly, and who will carry with him the good wishes of all who know him.

There was laid on our table within the year, as a present from the author, a short treatise "On the Motions of Fluids and Solids relative to the Earth's Surface," by W. Ferrel, Assistant upon the American Ephemeris. The work is intended to show that a complete mathematical investigation, setting out with the general equations of motion, leads to the same conclusions which were arrived at by the author previously, in a tract in which mathematical formulæ were avoided, and of which the subject was the modifying influence of the Earth's Rotation on the General Movements of the Atmosphere. The work belongs rather to meteorology and general physics; but it is possible that, by a slight extension of his investigation, the author might bring it within the department of physical astronomy, and contribute to our theoretical knowledge of the phenomena of the Sun's surface. The expression of our wish that he may resume the treatment of his problem under this other aspect, may induce him to earn our thanks by looking into another collection of observed facts, which much requires theoretical aid.

An immense addition has lately been made to our store of registered positions of stars, by the publication of the two first sections of Dr. Argelander's Bonn Catalogue, the first containing about 111,000 reduced positions, and the second about 105,000. A third section, which is already fully written out and in the printer's hands, will complete this great work. The corresponding charts, which Dr. Argelander has well regarded as necessary accompaniments of a Catalogue, are published to about the same stage of progress. Of the beauty of arrangement and execution of both Catalogue and Charts it is difficult to speak with moderation: to our view they are the perfection of astronomical workmanship in the branch they belong to. As very often happens, the execution of one work creates the necessity of another; and what has been for some time clear to a few will shortly be, if it is not now, plain to all, that what Argelander has done for the Northern hemisphere of stars must forthwith be done for the Southern. The plan is perfectly defined by his example, the limits of time and money equally so, and little else remains than to see whether an unofficial astronomer will seize the opportunity of distinction, or whether the Council of this Society, or some official Astronomer of this or a foreign country, shall take up the second half, and associate himself

with the veteran astronomer of Bonn in the crowning work of his life. Fellows of the Society will recollect that a report of this work was given by Argelander's desire in our number for December last.

The group of minor planets has received an accession of nine new members since the last Annual Meeting of the Society. The first, *Ausonia*, was discovered at Naples on the 11th of February by Professor De Gasparis; the second, *Angelina*, at Marseilles on the 6th of March, by M. Tempel; the third, *Maximiliana*, at Marseilles on the 10th of March, by M. Tempel; the fourth, *Maia*, at the Observatory of Harvard College, U.S., on the 10th of April, by Mr. Tuttle; the fifth, *Asia*, at Madras on the 18th of April, by Mr. Pogson; the sixth, *Leto*, at Bilk on the 29th of April, by Dr. Luther; the seventh, *Hesperia*, at Milan on the 29th of April, by M. Schiaparelli; the eighth, *Panopea*, at Fontenay-aux-Roses on the 5th of May, by M. Goldschmidt; the ninth, *Niobe*, at Bilk on the 13th of August, by Dr. Luther. The aggregate number of bodies in the group now amounts to 71.

Three new comets have been discovered during the past year. The first was discovered at New York by Mr. Thatcher. A parabolic orbit has been found to satisfy the observations. The second comet of the year must be regarded as one of the most splendid of modern times. It was first seen generally throughout Europe on the evening of the 30th of June, but it was subsequently found to have been seen as early as the 13th of May by Mr. Tebbutt, an amateur astronomer residing in New South Wales. During the first few nights after it became visible in Europe, the head shone with extraordinary splendour; the tail, also, exceeded 100° in length. In consequence of the unfavourable season of the year at which it appeared, it soon ceased to form a conspicuous object in the heavens; but it continued for a long time to be visible in telescopes even of moderate power. Several computers have formed elliptical elements for its orbit; but until the totality of the observations shall have been subjected to a complete discussion, no trustworthy results can be arrived at. The third new comet, announced since the last Annual Meeting of the Society, was discovered on the 29th of December at the Observatory of Harvard College, U.S., by Mr. Tuttle. It is still faintly visible as a telescopic object. A parabolic orbit appears to satisfy the observations.

Papers read before the Society from February 1861 to February 1862.

1861.

Mar. 9. Note on the Appearance of *Jupiter's* fourth Satellite during Transit. Mr. Burr.

Auxiliary Tables for Computing Log. Sine and Log. Tang. of Small Arcs. Mr. Drach.

On the Theory of the Regulation of Clocks by Galvanic Currents acting on their Pendulums. Mr. Airy.

On the Lunar Theory. Sir John Lubbock.

On the Appearance of *Jupiter's* third Satellite during Transit. Mr. Gorton.

On Prof. Wolf's latest Results on Solar Spots. Mr. Baxendell.

Results of Observations of Minor Planets. Mr. Airy.

On the Binary Star η *Cassiopeiæ*. Mr. Powell.

On a Method of Determining Longitude without a Clock. M. Radau.

Extract of a Letter to the Astronomer Royal. M. Hansen.

On a Solar Spot. Mr. Nasmyth.

Results of Observations of Solar Eclipse of 1860. Mr. Airy.

On the Persistency of two Light Patches in a Solar Spot. Mr. Birt.

On the Apparent Rotation of a Solar Spot. Mr. Birt.

April 12. Observations and Elements of Comet III. 1860. M. Moesta.

Morning Illumination of certain unnamed Lunar Craters. Mr. Birt.

On a Remarkable Appearance in *Jupiter*. Mr. Birt.

On a Micrometric Diaphragm. Mr. Casella.

Observations of *Saturn*. Mr. De La Rue.

Note on some Photographs of the Total Eclipse. Mr. De La Rue.

Extract of Letter to Rev. R. Main. M. Winnecke.

On Miscellaneous Subjects. M. Hansteen.

May 10. On a Remarkable Appearance of *Jupiter*. Mr. Barneby.

Observations of Small Planets, &c. Mr. Airy.

Discovery of a Comet (Thatcher's). Mr. Parkin.

Occultations of Stars by the Moon. Capt. Noble.

Note on one of the Comites of β *Geminorum*. Rev. T. W. Webb.

Morning Illumination of *Mare Humorum*. Mr. Birt.

Minima of Short-Period Variable Stars for 1861. Mr. Pogson.
Observations of Solar Eclipse, January 1861. Mr. Scott.
Announcement of Thatcher's Comet. Mr. Lassell.
Ditto ditto Sir J. Herschel.
Phenomena of *Jupiter's* Satellites. Rev. R. Main.
Letter to Dr. Lee, Discovery of *Leto*. M. Luther.
Observations of Thatcher's Comet. Mr. Gorton.
On the Secular Acceleration of the Moon's Mean Motion. Prof. Donkin.
Observations of Thatcher's Comet. Prof. Mitchell.
Observations on Prof. Hansen's Letter. M. de Pontécoulant.
Places of Comet I. 1861. Dr. Robinson.
Elements and Ephemeris of ditto. Mr. Pape.
On the Spiral Structure of the Great Nebula of *Orion*. Mr. G. P. Bond.
On the Light of the Sun, Moon, *Jupiter*, and *Venus*. Mr. G. P. Bond.
Observations of Small Planets. Mr. Airy.
On an Appearance observed in *Jupiter*. Mr. Baxendell.
Observations of Thatcher's Comet. Comm. Maury.
Discovery of New Planet (*Asia*). Mr. Pogson.
On the Shadow of the Ring of *Saturn*. Capt. Jacob.
Ditto ditto Mr. Lassell.
Observations of Small Planets, &c. Mr. Airy.
On the Variation of *η Argus*. Mr. Abbott.
On the Probable Identification of Anthelm's Variable of 1670. Mr. Hind.
On the Nomenclature of the Minor Planets. Mr. Hind.
Occultations observed at Highbury. Mr. Burr.
On the Penumbra of a Solar Spot. Mr. Birt.

Nov. 8. Observations of a Comet (Tebbutt's), &c. Commander Maury.
Table of Path of Moon's Shadow, Solar Eclipse, 1861. Mr. Hind.
Observations at Sea of a Comet. Mr. Krabbe.
On an Instrument for Comparing Colours. Mr. Birt.
Observations on *Cichus*, a Lunar Crater, &c. Mr. Birt.
Development of Horary Formulæ. Mr. Drach.
On the Form of the Shadow of *Saturn's* Ring. Rev. T. W. Webb.
On the Positions of the Radcliffe Catalogue. Mr. Safford.
Observations of Comet II. 1861. Mr. Ferguson.
Ditto ditto Mr. Abbott.

Observations of Comet II. 1861. Mr. Scott.
Ditto ditto Mr. Hough.
Ditto ditto Mr. Burder.
Ditto ditto Dr. Stothard.
Ditto ditto Mr. Tidmarsh.
Ditto ditto Mr. Carpenter.
Observations of Solar Spots. Major Lang.
Places of Comet II. 1861. Mr. Mansell.
Observations of Comet III. 1860. Sir T. Maclear.
Ephemeris and Elements of Encke's Comet. M. Encke.
On a Result derived by M. D'Abbadie from Observations of the Total Solar Eclipse, 1860. Mr. Airy.
On a new Observing Clock. Prof. C. P. Smyth.
Observations of the Lunar Crater *Plato*, with a volume of Drawings. Mr. Birt.
Extract of Letter to the Astronomer Royal. Mr. Hansen.
Occultation observed at Highbury. Mr. Burr.
Observations of Solar Spots, with Drawings. Rev. F. Howlett.
On a Proposed Isolated Flange for Conical Axes. Major Strange.
On Testing the Vertical Axes of Altazimuth Instruments. Major Strange.
On a Direct Method of Testing and Adjusting the Eye-piece of Altazimuth Instruments. Major Strange.

Dec. 13. On Solar Radiation. Mr. Waterston.
Right Ascensions and Declinations of Fundamental Stars observed at the Radcliffe Observatory, compared with the *Tabulæ Reductionum*. M. Wolfers.
Variations in the Light of *η Argus*. Mr. Powell.
On an Observed Minimum of R *Vulpeculæ*. Mr. Knott.
Note accompanying two Drawings of *Saturn*. Capt. Jacob.
On an extraordinary Solar Phenomenon. Mr. Wood.
Extract of Letter to Admiral Smyth. Mr. Spratt.
Extract of Letter to the Astronomer Royal. M. Secchi.
Observations of Comet II. 1861. Mr. Hartnup.
Transit of *Mercury*, Nov. 11, 1861. Mr. Hartnup.
Ditto ditto Mr. Lassell.
Ditto ditto Mr. Jeans.
Results of Observations of Small Planets. Mr. Airy.
Occultations observed at Maresfield. Capt. Noble.
On the Egyptian Period of 540 Years. Mr. Cooper.
Observations of Encke's Comet and *Saturn*. Mr. Horton.

On the Secular Acceleration of the Moon's Mean Motion. Mr. Cayley.
On the Transit of *Mercury*. Mr. Baxendell.
Observations of the Great Comet of 1861. Rev. R. Main.
On the Transit of *Mercury*. Rev. Prof. Chevallier.
1862. On the Progress of the Bonn Charts. Mr. Carrington.
Jan. 10. On the Circularity of the Sun's Disk. Mr. Airy.
Results of Meridional Observations of Small Planets. Mr. Airy.
Table of the Comparative Number of Observations of Small Planets made at all Observatories except Greenwich, and made at Greenwich. Mr. Airy.
Eclipse of the Sun observed at Nice. Mr. Talmage.
On the Solar Eclipse, Dec. 31, 1861. Lieut. Hardy.
Third Memoir on Disturbed Elliptic Motion. Mr. Cayley.
Note accompanying Photograph of the Sun. Mr. Selwyn.

List of Public Institutions and of Persons who have contributed to the Society's Library, &c. since the last Anniversary.

Her Majesty's Government.
The Secretary of State for India.
The Secretary of State for War.
The Lords Commissioners of the Admiralty.
The Board of Trade.
Royal Society of London.
Royal Asiatic Society.
Royal Geographical Society.
Royal Institution.
Royal United Service Institution.
Geological Society.
Linnean Society.
Zoological Society.
Photographic Society.
Society of Arts.
The Chemical Society.
British Association.
Art-Union of London.
Institute of Actuaries.
British Horological Institute.
University College, London.
The Radcliffe Trustees.
Society at Liverpool.

Syndicate of Cambridge Observatory.
Royal Society of Edinburgh.
Royal Irish Academy.
Royal Dublin Society.
The Government of New South Wales.
The Institute at Victoria.
L'Académie Impériale des Sciences de l'Institut de France.
Le Dépôt Général de la Marine.
The Society at Cherbourg.
Imperial Academy of Sciences, Vienna.
Royal Academy of Sciences, Berlin.
Royal Academy of Sciences, Munich.
Imperial Observatory, Vienna.
Royal Observatory, Munich.
Royal Observatory, Brussels.
Royal Observatory, Christiania.
Royal Observatory, Madrid.
Observatory, San Fernando.
Observatory, Milan.
Royal Academy of Sciences, Brussels.
The Italian Society.
The Society at Upsala.
Royal Academy of Sciences, Göttingen.
Imperial Academy, St. Petersburg.
The Society of Sciences at Leipsig.
The Society at Geneva.
The Turin Academy.
The University of Christiania.
The University of Utrecht.
American Philosophical Society.
American Academy of Arts and Sciences.
Smithsonian Institution.
The Franklin Institute.
Committee of the American Coast Survey.
The American Association.
Boston (U.S.) Library Trustees.
The Committee of Harvard College.
The Editor of Silliman's Journal.
The Editor of the New Zealand Examiner.
The Editor of the Athenæum.
The Editor of the Literary Gazette.
The Editor of the Critic.
The Editor of the London Review.

R. Abbatt, Esq.
F. Abbott, Esq.
G. B. Airy, Esq.
Prof. Argelander.
Adm. Bethune.

M. Biot.
G. P. Bond, E
J. A. Brown,
Dr. Bruhns.
Dr. Brunnow

T. S. Burt, Esq.
Prof. A. Caswell.
G. F. Chambers, Esq.
E. H. Coleman, Esq.
Warren De la Rue, Esq.
M. De Launay.
Prof. De Morgan.
S. M. Drach, Esq.
W. Ferrel, Esq.
Adm. Fitzroy.
Dr. Francis.
M. Gius. Gallo.
M. le Prof. Gautier.
Comm. Gilliss.
S. Gorton, Esq.
Dr. B. A. Gould.
Prof. Grant.
M. Grunert.
M. F. G. Gunther.
W. D. Haggard, Esq.
M. Hankel.
Prof. Hansen.
Prof. Heis.
J. Herapath, Esq.
M. Hofmeister.
Mrs. Hannah Jackson.
M. Kluck.
M. Kowalski.
W. Lassell, Esq.
Dr. Lee.
Prof. Von Littrow.
Sir J. W. Lubbock.
M. Mailly.
Sen. F. de P. Marquez.
Sig. Massimo.
M. H. Mohn.
M. M. J. Monrad.
M. L'Abbé Moigno.
H. A. Newton, Esq.
D. D. Owen, Esq.
M. Pape.
F. Perigal, Esq.
Dr. Peters.
M. Plana.
Prof. Plantamour.
M. Quetelet.
M. Reslhuber.
M. Roblin.
Capt. J. Rutherford.
Benj. Scott, Esq.
W. Scott, Esq.
M. J. F. J. Schmidt.
M. Seguin Ainé.
Capt. Shadwell, R.N.
Admiral Smyth.
Prof. C. P. Smyth.
W. E. Stanbridge.
M. O. Von Struve.
J. Todhunter.
A. C. Twining, Esq.
G. V. Vernon, Esq.
M. Le Verrier.
M. J. Villarceau.
Rev. T. W. Weare.
Rev. Dr. Whewell.
Mr. J. Williams.
M. Winnecke.
Dr. R. Wolf.

Address delivered by the President, Dr. Lee, on presenting the Gold Medal of the Society to Mr. Warren De La Rue.

Gentlemen,—In the Report which has been read to you, you have been informed that the Council have assigned the Gold Medal of the Society to our worthy Secretary, Mr. Warren De La Rue; and, as it is the custom, it becomes now my duty to explain to you, in a few words, the grounds of their decision.

You know that for many years Mr. De La Rue has devoted

the energies of his mind, a large expenditure, and such leisure as he could abstract from the complicated cares of an extensive and well-known commercial concern, to the earnest cultivation and systematic pursuit of practical Astronomy, and that he has been one of the most frequent contributors to our Evening Meetings, upon a variety of subjects — all requiring much knowledge, skill, and labour in their treatment.

Discoveries in the regions of Science so crowd upon us in our own times, that valuable inventions and striking results soon fade from the memory, and are lost in the brilliancy of those which rapidly succeed them.

I must therefore request your indulgence whilst I lay before you what it is that Mr. De La Rue has done to entitle him to receive, and which justifies the Council in awarding him the highest honour that it is in the power of the Royal Astronomical Society to bestow.

Mr. De La Rue has not only conducted the usual observations which are made at most private observatories, but he has directed the resources of a rare mechanical genius to improvements in the most approved methods of polishing the specula of reflecting telescopes, and perfecting the mechanical arrangements by which operations of such refined nicety are performed.

On this subject there can be no higher authority than Sir John Herschel, who, in an article on the *Telescope*, published in the *Encyclopædia Britannica*, says:—

"Such is Mr. De La Rue's mechanism, which has afforded very admirable results in the production of specula 13 inches in aperture and 10 feet focal length, the perfection of which is enhanced by his practice of bestowing the same care and precision on every step of the figuring of the speculum, from the grinding, the smoothing on a bed of hones, or rather a slab of slate cut into squares, carefully brought to the same figure, and to the figuring of the polisher itself, which being thus previously rendered almost perfect, the speculum is saved the rough work of having to figure the polisher for itself on every occasion of repolishing."

In a more private communication to myself on the same subject, Sir John adds that, "Mr. De La Rue's machinery, though grounded on Mr. Lassell's rotary principle, is by no means a servile imitation of Mr. Lassell, inasmuch as several distinct improvements have been introduced tending to distribute the polishing action more equally over the whole surface of the metal. One of these improvements consists in his interposition of a plate between the supporting plate and sliding plate of Mr. Lassell's traversing slide, which, being made to revolve, causes the traversing movement of the speculum to take place, not across the same diameter of its area, but at every stroke across a different diameter; and he also obviates the irregularity of the motion of Mr. Lassell's polisher

on its centre, by governing that rotation by mechanism, instead of leaving it to be determined by the excess of external over internal friction."

But it is in Celestial Photography that Mr. De La Rue has made his most important discoveries, and displayed an unfailing fertility of mechanical invention. Wisely acknowledging the growing vastness of the several departments of the same science, he has latterly, in a great measure, restricted his researches to the delineation of the various aspects of the heavenly bodies, through the medium of Photography.

It is only by acknowledging and adopting the principle of the division of labour that great results can be obtained, either in the pursuits of commercial industry or abstract science.

The days of the Admirable Crichton have long since passed away.

Indeed Lord Bacon himself, in the *Novum Organum*, well observes, in anticipation of the influence of this general principle:—

"Then men shall begin to find out their own powers, when all will not essay to do the same things, but each man will employ himself in the work for which he is most apt." *

Mr. De La Rue's claim to the special notice of astronomers, as a delineator of celestial objects through the medium of photography, does not rest on the absolute priority of his application of a well-known art in a new direction. It is rather based on the fact, that by methods and adaptations peculiarly his own, he has been the first to obtain automatic pictures of the Sun and Moon, sufficiently delicate in their detail to advance our knowledge regarding the physical characters of those bodies, and admitting of measurements astronomically precise.

The late Mr. Bond, of Cambridge, in the United States, in the year 1845, with the assistance of Messrs. Whipple and Bond, obtained good pictures of *α Lyræ* and of *Castor;* and that, in this year, Signor De Vico made an unsuccessful attempt to photograph the nebulæ in *Orion*.

At about the same time, or a little later, the Rev. J. B. Reade took photographs of *α Lyræ* at my Observatory at Hartwell, and at his own Observatory at the Vicarage of Stone.

Mr. Glaisher, writing, in 1851, as Reporter upon Philosophical Instruments in the Great Exhibition, Class X., and upon Mr. Bond's Daguerreotype of the Moon, taken in 1850, and which was placed in the Exhibition of 1851, says upon Photography,—"Let us now view Photography in its application to science: a process by which transient actions are rendered permanent, and which enables *Nature* to do her own work—or, in other words, which causes facts permanently to record themselves—is too well fitted for the purpose of science

* "Tum enim homines, vires suas nosse incipient, cum non eadem infiniti, sed alia alii præstabunt."—*Liber* 1, Aphor. cxiii.

to be long overlooked; but the difficulties to be overcome in its application have been and still are great, and the results proportionably few in number. We consider, however, that the commencement of a systematic application of the photographic process to the purposes of Astronomy is indicated by the daguerreotype of the Moon by Mr. Whipple; and great indeed will be the benefit conferred upon astronomical science when we obtain permanent representations of the celestial bodies and their relative positions through the agency of light."

Enlarged copies of Mr. Bond's photographs were laid before the Royal Astronomical Society in May of the same year. At the Meeting of the British Association of Science held at Ipswich in July 1851, under the Presidency of the learned Astronomer Royal, a daguerreotype of the Moon was shown to the members of the Mathematical Section by Mr. Bond; and his Royal Highness the Prince Consort, whose loss we now deeply deplore, was present on the occasion, and inspected the daguerreotype.

On the subject of the connexion of Photography and Chemistry with Astronomy, some interesting remarks appear in the admirable Lecture on the Sun, delivered by the respected Professor Walker before the British Association of Science under the Presidency of our esteemed Member Lord Wrottesley, in 1860, at Oxford.

There are several references to Celestial Photography in the various volumes of the *Comptes Rendus*, which can only be brought to your notice in the form of notes.*

It was the sight of these very promising daguerreotypes of Mr. Bond which, in 1851, first gave the impulse to Mr. De La Rue's labours in this direction. In 1852 he availed himself of the collodion process invented by Mr. Archer in the preceding year, and succeeded in obtaining a good picture of the Moon. In 1853 Professor Phillips obtained talbotypes of the Moon at York. In 1854 lunar photographs were secured at Liverpool under the supervision of our respected member Mr. Hartnup. In 1855 the Rev. J. B. Reade, who has distinguished himself by his discoveries in photography, obtained special notice

* 1849.—Vol. xxxviii. p. 241. "On the Observations of the Sun." By M. Faye.

1858.—Vol. xlv. p. 705 and following pages. "On the Photographs of the Eclipse of March 15, by MM. Porro and Quinet." By M. Faye.

1859.—Vol. xlviii. p. 174. "Report on a Memoir addressed by M. Liais on the occasion of the Total Eclipse of 1858, September 7."

1859.—Vol. xlix. "Second Memoir on the coming Eclipse of 18 July."

1860.—Vol. li. p. 965. "On the State of Astronomical Photography in France."

1861.—Vol. liii. p. 997. "On the Perfecting Meridional Observations of the Sun without an Observer." By M. Faye.

1862.—Vol. liv. pp. 43 to 159. "On Photographs of the Sun, taken by M. Belfort during the Eclipse of the 31st December last."

and honourable mention at the Paris Exhibition for his photograph of the Moon. Others, also, have been taken, at Rome by Signor Padre Secchi, at Brighton by Mr. Fry, and in the vicinity of London by Mr. Huggins. All these photographs possess merits of their own, and give decided promise of future and greater success.

Admiral Smyth, in the *Speculum Hartwellianum*, pp. 249–50 and 285, speaks of Mr. Bond's labour in Celestial Photography, particularly pointing out that, in 1857, a photograph was sent to the Astronomer Royal taking in the whole field between *Mizar* and *Alcor*, with such exactitude as to show their angles of positions and distances.

Mr. De La Rue's success in obtaining photographic pictures of the Moon possessing great sharpness of definition and accuracy of detail is owing to the happy combination of a variety of causes. Possessing a large mirror of such exquisite defining power that but few existing telescopes equal it in accuracy of definition, and brought into figure by *his own hands*, and by peculiar machinery of *his own contrivance*, he was at once freed from those imperfections in the actinic image which are of necessity inherent in the very best refractors, even when corrected most accurately for chromatic dispersion.

Mr. De La Rue at first had no clock-work apparatus to govern the motion of his telescope, and, after making several successful lunar photographs with the aid of the hand-gear of the telescope, he discontinued his selenographical experiments until he had removed from Canonbury to Cranford — a change of residence which, for the interests of Astronomy, he had for some time previously in contemplation. He then furnished his telescope — his own in a double sense — with a clock-work apparatus, which from time to time has passed through numerous alterations, and which is still in course of improvement. The mechanical problem before him, as the Fellows of this Society well know, was one of extreme complexity; for not only must the motion of the clock-work be perfectly smooth and equable, but it must also be capable of acceleration and retardation, to keep pace, so to speak, with the ever-varying velocity of the Moon in the heavens — a variation compounded of its diurnal motion and its ever-changing velocity in its orbit.

Lastly, by a rare and happy combination of chemical with mechanical skill, the time necessary for the exposure of the collodion film was materially shortened. The final result is this, — that images of the Moon have been repeatedly taken in the focus of the mirror, admitting of very considerable amplification, and exhibiting details on the Moon's surface sufficiently clear to admit of delineation under a microscope provided with a camera lucida, and thereby furnishing materials for a more accurate selenography than has heretofore existed.

Neither must we altogether omit that by stereoscopically

combining images of the Moon taken in different phases of her librations, more particularly enlarged copies eight inches in diameter, Mr. De La Rue has brought to light details of dykes, and terraces, and furrows, and undulations on the lunar surface, of which no certain knowledge had previously existed, and which I have had the exquisite pleasure of beholding in his Observatory at Cranford.

> "Man looks aloft, and, with erected eyes,
> Beholds his own hereditary skies."

I must now turn to a department in Celestial Photography, where Mr. De La Rue stands almost alone. I speak of *Heliography.* In April 1854, Sir John Herschel, in a letter to Colonel Sabine, recommended that daily photographic records of the Sun should be obtained at some observatory. Accordingly, the Royal Society placed at the disposal of the Kew Committee a sum of money to promote that object, and Mr. De La Rue was requested to administer the grant.

It becomes necessary to mention that Arago, in his elegant and popular work on Astronomy, translated by two eminent Fellows of our Society, states, that MM. Fizeau and Foucault, in 1845, obtained a photographic image of the Sun, and two spots on its disk, delineated with much apparent sharpness and accuracy; but, however this may be,* it is certain that no uniformly successful method of taking images of the Sun had been devised until Mr. De La Rue took up the problem for investigation.

Yet great as had been the difficulties in obtaining a really accurate and available picture of the Moon, they sink into insignificance when compared with those which had to be overcome in the photography of the Sun; for to obtain any automatic pictures of the Sun's photosphere available for practical purposes, it was found necessary to institute a series of preliminary experiments before actual operations could be successfully commenced. At first, nothing but burnt up and solarised pictures could be obtained by any method that had hitherto been devised, or with any the least sensitive of the media, that could be procured. Now, with the help of the Kew photoheliograph, as devised by him, and described in vol. xv. of the *Monthly Notices*, *heliography* is the easiest and simplest kind of astronomical photography. The method devised by Mr. De La Rue will enable any photographer of common average skill to take excellent heliographs. Pro-

* Respecting this photograph of the Sun, the Index of the *Comptes Rendus* has been searched all through, under the heads of *Arago*, *Photography*, *Soleil*, *Fizeau*, *Foucault*, *Daguerreotype*, and *Faye*, and no mention has been found whatever of the Sun's picture in 1845; and there has not been found any reference to it, excepting the plate in the body of the original work itself.

fessor Selwyn, of Cambridge, succeeds in getting good pictures of the Sun with the apparatus made for him by Mr. Dalmeyer, after the pattern of the Kew photoheliograph.

Mr. De La Rue announced at the last Meeting of the Society, that by applying the stereoscope to the examination of the Sun's disk, as he had formerly done in the case of the Moon, he had discovered that the faculæ on the surface of the Sun are to be found in the outer or highest regions of the solar photosphere.

I ought not to conclude without alluding to Mr. De La Rue's observations on the Solar Eclipse of 1860; but it must not be forgotten that *one* Daguerreotype picture was taken by Dr. Busch of the Solar Eclipse in 1851, and of the Solar Eclipse in 1860 *four* small pictures were also taken during the totality by Professor Monserrat under the direction of MM. Aguilar and Secchi at Desierto de las Palmas, in Spain.

Mr. De La Rue, during the progress of the same eclipse, took many large and exquisitely defined pictures, and secured two during the totality. I have no need to enter into details, as he has already described at several meetings of this Society, the numerical results that follow from the discussion, and the comparisons of the photographs which he took on that occasion. A paper, giving the result of his labours during the expedition to Rivabellosa, has been presented to the Royal Society, and is to be considered in March of this year.

Mr. De La Rue has invented an ingenious micrometer, lately exhibited at one of our Meetings, by means of which he fully confirms the hypothesis, that the coloured protuberances belong to the Sun, and renders it almost certain that the commonly received diameters both of the Sun and Moon require a correction.

More recently still, photographic pictures of the Sun have been obtained by Mr. De La Rue, not only exhibiting its well-known mottled appearance, but showing traces of Mr. Nasmyth's "willow leaves," and by the aid of stereoscopic pictures rendering it certain that the faculæ are elevations in the Sun's photosphere.

I need not enlarge on the wonderful discoveries which have been made and the astonishing results that have been obtained by Newton and his successors in this, the most fertile and exact of all the applied mathematical sciences. Neither would it become me, an humble but zealous worshipper of science, to hazard conjectures as to the *future progress of Astronomy*. And yet I cannot refrain from expressing my belief that the success already achieved by our friend warrants us in entertaining the hope that before long he will be able, with the aid of stereoscopic pictures, to exhibit to us the rose-coloured prominences depicted on the sensitive plates as plainly as the faculæ have already been photographed. The depths and the successive strata of those strange interlacing outliers within

the solar spots may be brought into tangible view. The different planes of *Saturn's* rings* will also come into relief, the belts of *Jupiter* may be manifested as portions of his dark body, and ere long the mountains and elevated continents of *Mars* will rise up into solidity before our delighted gaze.

I may also, perhaps, be permitted to remark, that while our great national and public Observatories,— indeed, I ought to say those of the civilised world as well,— are day by day adding to that enduring record of the transient phenomena of the heavens, which will enable future ages to reach the final finish and last perfection in the calculation of the tables of the motions of the Moon and the planets, to eliminate any element of error, however minute, and to detect any latent disturbing force, however feeble its effect: yet it is to *private Observatories* and to observations made in the remoter regions of starry space, that we are chiefly to look for new discoveries. It augurs well for the future, that there is no lack in our own day of such establishments, or of accomplished observers to use them. It is almost, if not altogether, needless to bring before you the names of Admiral Smyth, or Lord Rosse, or Mr. Lassell, or Lord Wrottesley, or Mr. Dawes, or Mr. Carrington, and a host of others familiar to many of you. The elliptic motions of binary stars round their common centre of gravity, the colours of others, the discovery of new planets, the calculation of cometary orbits, the laws of change in the *variable* stars, the sudden burst upon the sight of some stars, and the gradual evanescence of others, will afford for many generations suitable and exhaustless subjects of sustained astronomical research. The instant splendour and gradual decay of certain stars is one of the most wonderful facts recorded in the history of Astronomy. In 1572, Cornelius Gemma observed a star in the chair of *Cassiopeia*, transcending *Venus* herself in brightness. It was Hipparchus who first, I believe, noticed the sudden appearance of a star of singular brilliancy before unknown. By this strange discovery he was urged to construct a Catalogue of Stars visible to the naked eye, "that posterity might know whether time had altered the face of the heavens."

The art of Photography is of the very highest importance in the promotion of exact science.

* If the subject of the present address were not now of necessity confined to improvements in Celestial Photography, I should here refer at some length to those exquisite and unequalled hand-drawings by Mr. De La Rue, of *Saturn*, *Jupiter*, *Mars*, and the Comet of 1858, which have so often delighted and informed our Society. They have embodied with micrometrical accuracy the results of years of scrupulous and skilful labour; and, as an instance of the reliable nature of the results obtained, I may mention that, by placing under the stereoscope two of Mr. De La Rue's hand-drawings of *Saturn*, taken at two distant periods, the inclinations of the planes of the rings alluded to in the text become unmistakeably apparent.

It stereotypes, so to speak, for the use of all time to come, the present aspect of the heavens.

As astronomical observations ranged in tables record the present positions of the heavenly bodies, so Photography registers their present aspect. It may be, that the pictures of the Sun now taken will enable future ages to test the prediction of the poet,

> "The Stars shall fade away, the Sun himself
> Grow dim with age, and Nature sink in years."

If, then, we take collective note of all Mr. De La Rue's long and varied labours since the 14th March, 1851, when he became one of our members—such as the perfecting of the figures of mirrors, the graphic observations of the planets, the incomparable photographs of the Moon, the invention of the photoheliograph, the observations on the solar eclipse, the invention of the new method of obtaining numerical data, the application of the stereoscope to the examination of the surface of the *Moon*, and afterwards to that of the *Sun*—sure am I that the Society at large will unanimously approve of the award of their Medal made by the Council.

It may, however, be said by some ingenious critic that Photography is only an art, which bears but indirectly on the promotion of Astronomy, and that the reward of its successful manipulation is rather the province of those societies to confer which cultivate the art of Photography, or the science of Chemistry. But I cannot admit the justice of this view. What should we now say of the early Fellows of the Royal Society, if they had relegated Newton, when he invented the telescope that bears his name, to the Company of Spectacle Makers for his meed of praise? What should we now think, had the barren honours which grace scientific discovery been denied to such mechanical inventors as Hadley, or Dollond, or Sir William Herschel, or Lord Rosse, or Lassell? With them the name of De La Rue, I feel, will hold no inferior place.

(The President, then delivering the Medal to Mr. De La Rue, addressed him in the following terms):—

Mr. De La Rue,—In compliance with a resolution of the Council, I have the pleasing duty of placing in your hands the highest tribute to merit which they have in their power to bestow. The instruments made or improved by you, the important uses to which you have applied them, and the liberality with which you have communicated the results of your discoveries to the public, all indicate, in the opinion of the Council, a mind highly cultivated, whose energy has been directed, during many years, to the attainment of scientific perfection.

But your unceasing efforts and delicate manipulation in reducing the new and wonderful art of Photography to astronomical purposes, and in rendering Chemistry a handmaid to Astronomy, supply the more immediate motive of their approbation.

May Divine Providence continue to bestow upon you health and intelligence, and every social blessing, enabling you still further to illustrate the glory of the Creator, and to promote the rational enjoyment of our fellow-creatures.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President:

John Lee, Esq. LL.D. F.R.S.

Vice-Presidents:

G. B. Airy, Esq. M.A. F.R.S. Astronomer Royal.
Richard C. Carrington, Esq. F.R.S.
Arthur Cayley, Esq. M.A. F.R.S.
Rev. Robert Main, M.A. F.R.S. Radcliffe Observer.

Treasurer:

Samuel Charles Whitbread, Esq., F.R.S.

Secretaries:

Warren De La Rue, Esq. F.R.S.
Rev. C. Pritchard, M.A. F.R.S.

Foreign Secretary:

Admiral R. H. Manners.

Council:

Professor J. C. Adams, Esq. M.A. F.R.S.
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Charles Frodsham, Esq.
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Richard Hodgson, Esq.
Rev. Professor Selwyn, B.D.
Charles B. Vignoles, Esq. F.R.S.
Charles V. Walker, Esq. F.R.S.

Printed by Strangeways and Walden, Castle St. Leicester Sq. and Published at the Apartments of the Society, March 13, 1862.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXII. *March* 14, 1862. No. 5.

Dr. LEE, President, in the Chair.

J. Norman Lockyer, Esq., Wimbledon,
Rev. Edward Crofton, Heene, Sussex; and
J. J. Cole, Esq., 24 Essex Street, Strand,

were balloted for and duly elected Fellows of the Society.

M. Charles Delaunay, Paris, was balloted for and duly elected an Associate of the Society.

Collected Works of Gauss.

The Academy of Sciences of Göttingen announce the publication of the Collected Works of Gauss, including the manuscripts left at his decease. The Works will appear in seven volumes, quarto, under the titles,—

I. Disquisitiones Arithmeticæ.
II. Hohëre Arithmetik.
III. Analysis.
IV. Geometrie und Methode der kleinsten Quadrate.
V. Mathematische Physik.
VI. Astronomie.
VII. Theoria Motus Corporum Cœlestium;

the *Theoria Motus* to appear when the copyright interest therein has expired. The contents of the several volumes are given in No. 1348 of the *Astronomische Nachrichten.*

The Works are to be published by subscription, which may be either for the whole or for the separate volumes; the subscription price to be hereafter fixed, but to be at about the rate of four thalers for a volume of from fifty to sixty sheets. Subscriptions may be addressed, post-free, "An das Secretariat der Königlichen Gesellschaft der Wissenschaften zu Göttingen." On completion, the Works will be sold in the ordinary course, at the rate of six or seven thalers per volume. The impression has begun, and will be carried on so that the first six volumes may at latest appear within five years.

On the Perturbations of Uranus and the Mass of Neptune. By Truman Henry Safford, Assistant at the Observatory of Harvard College.

In the determination of the mean distance of the satellite of *Neptune*, and the consequent evaluation of that planet's mass, the faintness of the satellite has proved a great difficulty; so that different observers have differed systematically *inter se*, although each one is quite consistent with himself.

For instance, the mass of *Neptune*, from O. Struve's observations of the satellite, comes out $M = \frac{1}{14491} \pm 0{\cdot}02431$ M, while Prof. G. P. Bond has deduced $M = \frac{1}{19400}$ from his father's and his own observations.

The perturbations of *Uranus*, by means of which *Neptune* was originally discovered, are, of course, adequate to determine its mass; and it would naturally be expected that the probable error of such a result would be much less than the difference between the numbers cited above.

Prof. Peirce, employing, I believe, the same observations as Leverrier did in his "Recherches sur les Mouvements de la Planète *Herschel* (dite *Uranus*)," has deduced (*Ast. Nach.*, No. 637) the result that, in general, a mass of *Neptune* nearly $\frac{1}{20000}$ will represent the motions of *Uranus* considerably nearer than a value more closely approaching to Struve's.

I was led to take up this question partly because it had been, some years ago, made the subject of a prize question by the Haarlem Society of Sciences (which, so far as I know, was not answered within the specified time), and partly because Struve's mass of *Neptune* seems to have been adopted by some high authorities; by Leverrier as, at least, a provisional value.

The perturbations of *Uranus* produced by *Neptune*, assuming $\frac{1}{19400}$ as the disturbing mass, were computed by the method of mechanical quadratures. These were then added to the perturbations of heliocentric longitude derived from Leverrier's theory, and the theory thus computed (so far as heliocentric longitude is concerned) was compared, for one date in each year, with the results from Bouvard's Tables contained in the *Greenwich Planetary Reductions*, and with the *Nautical Almanac* since 1836 inclusive, to 1858.

Errors of these latter theories in heliocentric longitude were obtained from the *Greenwich Planetary Reductions*, and the *Results of the Greenwich Observations*, 1836–1858; and thus the errors in heliocentric longitude of the present provisional theory were obtained.

It is proper to mention here, that Bradley's observation of 1753 was omitted here, as it seemed desirable to found the result on modern observations, using the ancient ones as a confirmation; also that where the error of radius vector in Bouvard's Tables was found sensible, observations in the neighbourhood of opposition were used.

The Paris observations (1801 to 1819), the Greenwich (1831 to 1835), and the Konigsberg observations (1814 to 1846), were also used; the first series, as reduced by Leverrier, in the *Annales de l'Observatoire Impériale*, and the remainder after Flemming's (*Ast. Nach.* No. 755 *et seq.*), and Applebaum's (*Königsberg Observations*, vol. xxxii. p. 210 *et seq*) reductions. It is known that the observations at these Observatories were made chiefly near opposition; and, indeed, Flemming has computed (with a few mistakes) the opposition as it is derived from observations made near it for a good many years.

Of course, every effort has been made to put all these reductions in the state in which they would have been if uniform star-places and other elements had been used in making them.

The results were found to indicate with some degree of probability, by a mere inspection, that the disturbing mass would need but little change. In fact, a preliminary solution of a set of twenty-six equations obtained by equating the residual errors of this first theory (taking the means of three years together) to functions of unknown variations of the elements of *Uranus* alone, represented these equating with final remainders of less than $4''$ in every case.

It seemed expedient, however, to introduce a variation of *Neptune's* mass as an unknown quantity; and after another preliminary solution, whose object was to obtain means for combining (as before) the observations of three years together, the weights were assigned to different series of observation, according to a somewhat arbitrary distribution. A final solu-

tion then gave the mass of *Neptune* $M = \frac{1}{20039}$ with a probable error in the denominator $\pm$ 295.

The increase of *Neptune's* mass to $\frac{1}{14491}$ would have the effect of nearly quadrupling the mean error of observation; and would, in fact, leave intolerable discrepancies in several places.

An investigation now made into the geocentric longitudes derived from observations made before *Uranus* was actually recognised as a planet, gave eminently satisfactory results. The following is the comparison, with the observations used by Leverrier, p. 138 of his *Recherches*, "to form the first twelve equations, which are all ancient:"—

Year.	No. Obs.	Observer.	C — O.
			$''$
1690	1	Flamsteed	− 5·0
1712	1	,,	+ 18·1
1715	2	,,	+ 5·9
,,	1	,,	+ 0·8
1750	1	Lemonnier	+ 4·0
,,	1	,,	− 1·6
1753	1	Bradley	+ 0·2
1756	1	Mayer	+ 0·9
1764	1	Lemonnier	− 0·4
1768	2	,,	− 2·3
1769	6	,,	− 5·3
1771	1	,,	+ 5·0

Flamsteed's observation made in 1712 is uncertain, on account of the rate of the clock. It is isolated about 2½ hours from the comparison stars; and, during an interval of twenty or more days, for which there are only one night's observations, the clock was often very irregular.

Grouping the observations, as Leverrier has done (p. 239 of the Memoir above cited), we shall have as residual errors,—

	Error.	Leverrier's Limit.
	$''$	$''$
1690	− 5	25
1712–15	+ 8	15
1750	+ 1·2	15
1753–56	+ 0·55	10
1768–69	− 4·55	10

All these observations are, therefore, represented much within the limits given by Leverrier, p. 240 of his *Recherches*.

On the Proper Motion of Sirius in Declination. By Truman Henry Safford, Assistant at the Observatory of Harvard College.

It is well known that *Sirius* exhibits irregularities of proper motion, both in Right Ascension and Declination. Bessel (*Ast. Nach.* Nos. 514–16), and Dr. C. A. F. Peters, in a Memoir, "Ueber die eigene Bewegung der *Sirius* (Habilitationsschrift), Königsberg, 1851," also republished in vol. xxxii. of the *Astronomische Nachrichten,* have investigated the variations of proper motion in Right Ascension. The hypothesis which these distinguished astronomers have adopted is, that the motions are performed around some centre of gravity, which is not at *Sirius* itself. This involves the idea of a dark body of considerable mass, whose attraction is exerted to draw *Sirius* from its hypothetical motion in a straight line. Dr. Peters does not, as I understand, insist that the dark body is of greater mass than *Sirius* itself; so that it may (possibly) be of planetary character.

The object of the present discussion is merely to show the character of the irregularities in Declination, and to examine whether they are reconcilable with the results derived from the Right Ascensions. The quantity which I have used in this investigation is the deviation of *Sirius* in Declination from the *Tabulæ Regiomontanæ*, less mean of the corresponding deviation for the four stars *Spica*, α^2 *Libræ*, *Antares*, and α^2 *Capricorni*. These have the advantage over absolute declinations, that there is thus a possibility of avoiding a portion of the systematic errors to which most astronomical determinations are exposed. The mean of the Declinations of the four comparison stars is very nearly that of *Sirius*.

Bessel's Declinations are (it is well known) more than a second further south than other determinations, at a South Declination equal to 16°; and in a matter of such delicacy it becomes necessary to scrutinise the observations quite closely.

Without a new reduction of Piazzi's and Pond's observations, it would be difficult to use them as fully authentic. The chief cause of disturbance seems to be the fact that Piazzi and Pond both used Bradley's factor for the thermometric variation of the refraction; and this value is largely erroneous. If *Sirius* is observed at a mean temperature different from that at which the four stars above mentioned are observed, an error is thus introduced. The refraction being large, it becomes of too great influence.

The effect (probably) of this error in the factor of the thermometric correction may be seen on comparing Olufsen's reduction of Pond's observations of 1822 with Pond's own. As α^2 *Capricorni* is not contained in Pond's reduction, we will (at

this period) omit it in considering Olufsen's. We find that by Pond's own reduction of his observations of 1822, *Sirius* is $1''\cdot68$ further north than the *Tabulæ Regiomontanæ* make it; that *Spica*, a^2 *Libræ*, and *Antares*, are (in the mean) $4''\cdot55$, and, therefore, that *Sirius* is $2''\cdot87$ too far south, as compared with these three stars. But, by employing Olufsen's reduction, *Sirius* is shown to be $0''\cdot33$ too far north, and the three other stars in the mean $0''\cdot95$; so that *Sirius*, as compared with these three, is $0''\cdot62$ too far south.

The comparisons here given have been taken from Bessel's table (*Ast. Nach.* No. 73, p. 7).

The numbers which have been used are as follows, nearly:

			q'.
Bradley	1755		−0·7
Piazzi	1805		(−0·5)
Pond	1813		(+0·6)
Bessel	1820		−0·4
Pond	1822	(Olufsen)	−1·5
Struve	1824		−1·6
Pond	1826		(−2·1)
Argelander	1830		−1·0
Taylor*	1832		−1·7
Pond	1833		(−2·6)
Henderson*	1833		−1·5
Airy	1834		−2·4
Maclear*	,,		−1·7
Henderson	1837		−0·8
Airy	1838		−0·4
Busch	,,		−0·4
Bessel	1843		+1·1
Airy	1844		+1·9
,,	1850		+2·1
Moesta*	1855		+0·8
Airy	1856		+1·5

* From observations near and south of the equator.

It may seem singular that the position of the *Fundamenta* for 1755, and Bessel's for 1820, should seem to differ at all from the *Tabulæ Regiomontanæ*, when the latter were calculated from the former. The numbers given above, for those Catalogues, are merely the corrections necessary, on account of the alteration in mutation, rendered necessary by more modern observations. Corrections have been applied also to Olufsen's reduction of Pond ($-0''\cdot26$), to Argelander ($+0''\cdot40$), and to Busch ($-0''\cdot39$); these being the excess of the correction

taken from Table IV. on p. xxvi. of Struve's *Positiones Mediæ* for *Sirius* over the similar correction for the four stars compared.

Our table includes, then, the deviation from the *Tabulæ Regiomontanæ* of the Declination of *Sirius*, as observed by different observers, with (in general) different instruments, less the mean of the similar corrections for *Spica*, a^2 *Libræ*, *Antares*, and a^2 *Capricorni;* corrected in the cases above specified for error of mutation.

On referring to Dr. Peters' memoir, we shall at once find that, if his hypothesis be adopted, the numbers given above will be represented by the formula

$$q' = b' + f' + c'\,(t - 1800) + g' \cos u + h' \sin u,$$

where b' denotes the correction of the Declination for 1800 of the centre of gravity of the system, c' the correction of Annual Proper Motion; each of these quantities to be applied to the *Tabulæ Regiomontanæ* values for *Sirius* itself, to get declinations in general accordance with Bessel's other declinations; g', h', being constants depending on the elements of the orbit of *Sirius* around the centre of gravity, and $f' = -g'e$, where e is the excentricity; u being also the excentric anomaly of *Sirius* in its orbit.

If, then, we adopt Peters' Elements V.,

Passage of the Lower Apside	1791·431
Mean Yearly Motion	$7^{\circ}{\cdot}1865$
Excentricity (e)	0·7994

we shall have

$$u - e \sin u = 7^{\circ}{\cdot}1865\,(t - 1791{\cdot}431),$$

t being the date in years, and the predicted values of sin u cos u can be easily computed. But, in the first place, it must be seen whether any hypothesis of uniform motion will represent the observations, excluding Bradley's of about 1755. It is found that a correction $-4''{\cdot}18 + 10''{\cdot}30 \left(\frac{t - 1800}{100}\right)$ will materially lessen the errors. This correction, however, requires that Bessel's Bradley's place for 1755 be erroneous by $8''{\cdot}7$; and that this is impossible is shown by the near agreement of Lacaille's and Mayer's places for 1750 and 1756 with the *Tabulæ Regiomontanæ*.

But the actual formula deduced from the observations by the substitution of Peters' hypothesis is

$$-0''{\cdot}56 + 0''{\cdot}0202\,(t - 1800) + 1''{\cdot}47 \sin u + 0''{\cdot}51 \cos u,$$

and this leaves, as residual errors,

			C—O.	
			″	
Bradley			0·0	
Piazzi	1805		(+0·8)	
Pond	1813		(−0·6)	
Bessel	1820		−0·6	
Pond	1822	(Olufsen)	+0·3	
Struve	1824		+0·4	
Pond	1826		(+0·8)	
Argelander	1830		−0·5	
Taylor	1832		+0·2	
Henderson	1833		0·0	
Pond	1833		+1·1	(14 observations.)
Airy	1834		+1·0	
Maclear	1834		+0·3	
Henderson	1837		−0·4	
Airy	1838		−0·5	
Busch	1838		−0·4	
Bessel	1843		+0·5	
Airy	1844		0·0	
,,	1850		−0·4	
Moesta	1855		+0·5	
Airy	1856		−0·4	

There can be hardly any doubt, then, that Bessel's and Peters' hypothesis does actually represent the observed Declinations of *Sirius*, although the evidence on which it has been previously urged depends entirely on the Right Ascensions.

It may be noticed that Calandrelli's statement, that the *Greenwich Twelve-Year Catalogue* for 1845 (1844) is materially in error, is at once refuted by the almost perfect agreement given above. The phenomena which *Sirius* presented about 1841, that being according to Peters (confirmed by the results above) the time of the passage of the lower apside, are sufficiently remarkable; rapid variations both in Right Ascension and Declination were then taking place.

Extract of a Letter from Mr. A. Auwers to the Rev. R. Main, dated Königsberg, 1862, February 21, on the Irregularity of the Proper Motion of Sirius, and on a Missing Nebula.

(*Communicated by the Rev. R. Main.*)

For some months I have been attempting to represent the observed Declinations of *Sirius* from 1755 to 1859, in which a

periodical change of proper motion is very conspicuous, by a formula grounded on the elements of Peters; and I found the correction q' of the declinations of the *Tabulæ Regiomontanæ*, relatively to β *Orionis* and α *Hydræ*, from thirty-one equations,

$$q' = +0''{\cdot}10 + 0''{\cdot}0158\,(t-1800) + 1''{\cdot}536 \sin u - 0''{\cdot}025 \cos u,$$

where

$$u - 0''{\cdot}7994 \sin u = 7^\circ{\cdot}1865\,(t - 1791{\cdot}431),$$

The values of q' from the *Greenwich Six-Year Catalogue*, and from the observations from 1854 to 1859, are

$$-0''{\cdot}14,\ +2''{\cdot}36,\ +2''{\cdot}51,\ +2''{\cdot}65;$$

the elements give for these epochs

$$-0''{\cdot}66,\ +2''{\cdot}14,\ +2''{\cdot}36,\ +2''{\cdot}03,$$

and therefore completely justify your defence of the Greenwich declinations against the objections of Calandrelli.

It has only very recently been known to me that Mr. Safford has made a similar investigation, using, however, different stars of comparison. If the corrections q' of the declinations of *Sirius* be deduced from the formula given above, and from that communicated in No. 28 of the *Astronomical Notices*, we obtain:—

According to Safford,

$$q_{,}' = -1''{\cdot}00 + 0''{\cdot}0104\,(t-1800) + 1''{\cdot}47 \sin u + 0''{\cdot}51 \cos u$$

According to my calculation,

$$q_{,}' = -0''{\cdot}60 + 0''{\cdot}0003\,(t-1800) + 1''{\cdot}536 \sin u - 0''{\cdot}025 \cos u$$

a satisfactory agreement with reference to the materials employed. This in fact is not unexceptionable, the probable error of a determination of declination being, according to Safford, $\pm\,0''{\cdot}30$, and according to me, $\pm\,0''{\cdot}32$, while at the same time I have found for *Procyon* an orbit, which represents the observed places with the probable errors $\pm\,0''{\cdot}17$. The reason of the lesser agreement of the Declination of *Sirius* arises plainly from the circumstance that this star for European Observatories culminates at too low an altitude. For a new determination of the elements of its orbit from all the observed Right Ascensions and Declinations, which I contemplate undertaking, determinations of southern Observatories would be very desirable. Is it known to you whether the observations of the Cape of Good Hope since 1834 are reduced?

I observed several times in February and March, 1858, the interesting Nebula found by Hind in 1852, and observed by D'Arrest and Breen in 1855 and 1856, and finally missed by D'Arrest in October 1861. In 1858 I found it to be fainter than it ought to have been, according to the description of D'Arrest in 1855. At that time I saw it with a telescope of 4⅓ inches aperture, but, in January and September 1861, I could not find it with the 6-inch heliometer, nor have I been able to find it after repeated searches during the last five months. The variability of the accompanying star I remarked in November 1861, as I found it to be of the 11–12 magnitude, while in 1858 it was of the 10th magnitude. At present it appears to be getting somewhat brighter, and is of the 11th magnitude.

Extract of a Letter from Mr. A. Auwers to the Rev. R. Main, dated Königsberg, 1862, March 21, on the Orbit of Procyon, and on the Positions of the Radcliffe Catalogue.

(*Communicated by the Rev. R. Main.*)

I am much obliged for your answer to my letter of the 21st of February. Learning from your letter that the results of my researches on variable Proper Motions may perhaps be interesting to you, I add to the formula for correcting the tabular Declinations of *Sirius*, given in my preceding letter, also the elements of the orbit of *Procyon*, derived from all available observations of Right Ascension and Declination, made between 1750 and 1860:—

Epoch of minimum in R.A.	$=\mathrm{T}$	$1795{\cdot}5676$	Probable error		$\pm 0^{\mathrm{y}}{\cdot}4457$
Time of revolution	$=\mathrm{U}$	$39^{\mathrm{y}}{\cdot}972$	„	„	$\pm 0^{\mathrm{y}}{\cdot}4043$
Mean yearly motion	$=n$	$9^{\circ}{\cdot}00634$	„	„	$\pm 0^{\circ}{\cdot}09110$
Radius of circle	$=r$	$1''{\cdot}0525$	„	„	$\pm 0''{\cdot}0275$

There is not the least trace of ellipticity indicated by the observations. The corrections to be applied to the Right Ascension of Wolfers' *Tabulæ Reductionum*, relative to the mean of the stars *Aldebaran*, *Rigel*, *α Orionis*, *Pollux*, *α Hydræ*, and *Regulus*, and to the Declination of the same tables, relative to *α Ceti*, *α Orionis*, *α Serpentis*, *γ*, *α*, *β Aquilæ*, and *α Aquarii*, are the following:—

$$d\alpha = +0^{\mathrm{s}}{\cdot}0033 \; -0^{\mathrm{s}}{\cdot}001192\;(t-1830) \; -0^{\mathrm{s}}{\cdot}0705 \cos n\,(t-\mathrm{T}),$$

$$d\delta = +0''{\cdot}201 \; +0''{\cdot}00931\;(t-1830) \; +1''{\cdot}853 \sin n\,(t-\mathrm{T}).$$

The mass of the dark companion of *Procyon* is probably not less than three-quarters of the mass of the Sun.

Variations have also been supposed to take place in the proper motions of α *Virginis*, α *Hydræ*, and β *Orionis;* but in all these cases the results of my researches are entirely negative, showing with evidence that there exist no variations in the motions of these stars.

The reason of my again taking the liberty to write to you is a paper "On the Positions of the Radcliffe Catalogue," in No. 9 of vol. xxi. of the *Monthly Notices*. It has not been before now that I have learnt that Mr. Safford calls attention by this paper to a rather large discrepancy between a formula, given by me in No. 1300 of the *Astronomische Nachrichten*, for correcting the Declinations contained in the vol. i.–xiv. of the *Radcliffe Observations*, so as to make them agree with Wolfers' *Tabulæ Reductionum*, and the corrections to be applied to these Declinations according to the late Mr. Johnson's investigation in vol. xv.

The formula has been derived, as it is stated in the *Astronomische Nachrichten*, from Mädler's comparisons (*Dorpat Observations*, xiv.), and represents them very accurately between the Declinations 40° and 80°. But now the definitive Declinations of the Radcliffe Catalogue having been substituted to the provisionally adopted ones of the *Observations*, I have thought it advisable to undertake a direct comparison of the first with some other Catalogues, the relations of which to the *Tabulæ Reductionum* are accurately known.

There occur 231 stars of the Radcliffe Catalogue in Argelander's Abo Catalogue reduced to 1845, and corrected for the difference between the constants of Nutation adopted in the construction of the Catalogue and the computation of the Proper Motions and the true value $=9''\cdot223$; the correction to be applied to the Declinations being $+0''\cdot244 \sin(\text{R.A.}-0^h36^m)$, and to the Proper Motions $0''\cdot0081 \sin(\text{R.A.}+0^h55^m)$. Argelander's Declinations differ from Johnson's (corrected, where necessary, according to the introduction of the Catalogue) by the following quantities, A—R, to which I have also added the differences W—A between the *Tabulæ Reductionum* and the Abo Catalogue, reduced to the year 1845, and the differences W—R, resulting from the addition of the numbers A—R and W—A.*

Decl.	A—R.	Stars Cmp.	W—A.	W—R.
°	″ ″		″	″
−16·6	+1·45 ±0·15	17	−0·72	+0·73
− 4·9	+1·10 ±c·19	11	−0·63	+0·47
+ 4·9	+0·35 ±0·13	24	−0·53	−0·18
+14·9	+0·73 ±0·18	12	−0·41	+0·32

* Four stars presenting large differences have been excluded in taking the means.

Decl.	A — R.	Stars Comp.	W — A.	W — R.
°	″ ″		″	″
+25·9	−0·41 ±0·21	9	−0·25	−0·66
+35·9	−0·50 ±0·24	7	−0·09	−0·59
+41·7	−0·12 ±0·10	38	−0·01	−0·13
+48·8	+0·12 ±0·11	31	+0·10	+0·22
+53·3	+0·53 ±0·12	27	+0·18	+0·71
+62·5	+0·45 ±0·14	19	+0·26	+0·71
+69·8	+0·67 ±0·15	17	+0·27	+0·94
+76·7	+0·92 ±0·22	8	+0·24	+1·16
+84·1	+0·99 ±0·22	7	+0·15	+1·14

In a similar way I have found by 408 stars common to the Radcliffe Catalogue and Struve's *Positiones Mediæ* (including 93 already made use of in the preceding investigation),

Decl.	S — R.	Stars Comp.	W — S.	W — R.
°	″ ″		″	″
−15·4	+1·81 ±0·24	10	−0·82	+0·99
+ 2·0	+0·79 ±0·16	19	−0·83	−0·04
+16·2	+0·52 ±0·17	20	−0·39	+0·13
+30·6	−0·49 ±0·18	18	−0·23	−0·72
+41·1	+0·08 ±0·09	70	−0·25	−0·17
+48·6	+0·29 ±0·10	53	−0·21	+0·08
+55·1	+0·51 ±0·08	80	−0·09	+0·42
+62·4	+0·48 ±0·10	56	+0·11	+0·59
+69·3	+0·77 ±0·12	37	+0·18	+0·95
+76·6	+0·53 ±0·15	25	+0·14	+0·67
+83·7	+0·89 ±0·17	20	+0·02	+0·91

The mean of the two nearly agreeing systems of values W—R becomes, for the circumpolar stars,

Decl.	W — R.	Stars.	Formula.	C — O.
°	″		″	″
41·4	−0·15	108	−0·16	−0·01
48·7	+0·13	84	+0·16	+0·03
55·2	+0·49	107	+0·41	−0·08
62·4	+0·62	75	+0·16	+0·04
69·5	+0·95	54	+0·84	−0·11
76·6	+0·79	33	+0·95	+0·16
83·8	+0·97	27	+1·02	+0·05

Assuming the Weights of these numbers nearly proportional to the numbers of the stars compared, I have derived from them the following formula:—

$$W-R = -2''\cdot53 + 3''\cdot59 \sin \delta.$$

The column headed C−O contains the small remaining differences between this formula and the observed values. Tabulating the values of the formula with changed sign, we receive the following

Corrections of the N.P.D. of the Radcliffe Catalogue.

N.P.D.		Observ. vol. i.–xiv. Johnson.	Formula.
0°	−1″·06	+0″·92	−0″·14
5	−1·05	+0·97	−0·08
10	−1·01	+1·03	+0·02
15	−0·94	+1·10	+0·16
20	−0·84	+1·15	+0·33
25	−0·72	+1·23	+0·51
30	−0·58	+1·28	+0·70
35	−0·41	+1·34	+0·93
40	−0·22	+1·38	+1·16
45	−0·01	+1·43	+1·42
50	+0·22	+1·46	+1·68

In the vicinity of the pole, therefore, the provisionally adopted Declinations of the *Observations* agree far better with the *Tabulæ Reductionum* than the corrected Declinations of the Catalogue; but in Polar Distances greater than 25°, the opposite takes place.

The differences given by the Southern stars are somewhat irregular and less sure; the number of these occurring in the Catalogue being not at all great, I have thought it sufficient to join the values found between 54° and 106° N.P.D. to the circumpolar formula by drawing a simple curve, from which I have taken the following corrections of the N.P.D. of the Catalogue:—

N.P.D.		N.P.D.	
55°	+0″·5	85°	−0″·1
60	+0·6	90	−0·3
65	+0·6	95	−0·5
70	+0·5	100	−0·7
75	+0·3	105	−0·8
80	+0·1	110	−1·0

I may also mention that the differences between the Radcliffe Declinations and Argelander's in the hours 3−11 of R.A. are on the whole smaller (about 0″·5) than in the other hours; but in the comparisons with Struve, no such variation being shown, I have not had regard to it. The probable error of a difference A−R, by one star, is found from the circumpolar

stars to be $\pm 0''\cdot622$, and that of a difference S—R is found to be $\pm 0''\cdot743$. The probable error of a Declination of the Abo Catalogue being $\pm 0''\cdot27$ and that of the reduction to 1845 being $\pm 0''\cdot16$, the probable error of a Declination of the Radcliffe Catalogue becomes, from the comparisons with Argelander, $\pm 0''\cdot54$.

Observatory, Königsberg, March 21, 1862.

Observations of Transit of Mercury, Solar Eclipse, and Occultation of Venus. By M. C. Bulard, Director of the Observatory of Algiers.

(*Communicated by the Astronomer Royal.*)

Transit of Mercury, 1861, *November* 11, *observed at the Observatory of Algiers.*

Egress, exterior* contact.

	h m s	
	21 31 50·673	Algiers Mean Time,
or	21 28 28·073	Paris Mean Time.

Solar Eclipse of 1861, *December* 31.

The disturbed state of the country prevented M. Bulard from reaching the line of totality. The following observations were made at Ouargla:—

Latitude 31° 57′ 9″·0 N.; Longitude (approximate) $21^{m}\ 5^{s}\cdot33$ E. of Greenwich.

	h m s	
First Contact at	2 18 3·8	Ouargla Mean Time.
Last Contact at	4 41 16·1	,, ,,

Occultation of Venus by the Moon, 1862, *February* 1, *observed at Laghouat.*

Latitude 33° 48′ 10″ N.; Longitude (approximate) $11^{m}\ 33^{s}$ E. of Greenwich.

	h m s	
First Contact at	6 55 10·558	(Apply. Laghouat M. T.).
Disappearance of Left Horn of Venus	6 55 58·515	,,
Disappearance of Right Horn ...	6 56 0·011	,,

(as seen in an inverting telescope).

* There are the words of M. Bulard; but his diagram shows that it was internal contact. G. B. A.

hemeris of the Long Period Variable Stars for 1862. By N. R Pogson, Director of the Madras Observatory.

e initials in the last column indicate respectively, Messrs. Argelander, Baxendell, Krüger, Pogson, Schönfeld, and Winnecke.

r.	Probable Mag.	Mean Place, 1861. R.A. h m s	N.P.D. ° ′	Times of Maxima.	Authority.
ium	9·5	0 24 46	76 14	April 24, Sept. 14	S.
iopeiæ	2·0	0 32 35	34 14	March 20, June 7, Aug. 25, Nov. 12	A.
um	9·0	1 10 15	81 49	Possibly in August. Very uncertain	—
ium	7·5	1 23 25	87 50	Possibly in May. Uncertain ...	—
tis	8·0	2 8 10	65 36	Jan. 15, July 17	B.
	2·0	2 12 17	93 37	July 3	A.
ri	8·0	4 20 38	80 9	May 7	W.
i	10·0	4 21 32	80 22	March 11	W.
nis	9·0	4 51 22	82 5	June 19	W.
nis	1·0	5 47 36	82 37	January and July. Uncertain ...	—
inorum	7·3	6 58 56	67 5	Jan. 25	P.
. Min.	8·0	7 1 0	79 46	April. Uncertain	—
Min.	7·5	7 25 7	81 23	July 23	W.
inorum	9·2	7 34 38	66 13	August 14	P.
inorum	8·9	7 40 54	65 55	May 13	P.
inorum	9·1	7 46 48	67 38	Jan. 21, April 28, Aug. 2, Nov. 7	P.
cri	6·0	8 8 51	77 51	January 17	B.
cri	9·0	8 27 45	70 37	July 3	W.
ræ	8·5	8 46 16	86 24	January 22, October 5 ...	W.
cri	12·0	8 48 40	69 37	At minimum, December 26 ...	W.
ræ	6·5	8 48 51	98 37	February 22, December 11 ...	W.
nis	5·0	9 40 2	77 55	Oct. 13. Minimum (10·0) May 29	P.
. Maj.	7·0	10 34 41	20 29	April 29. Minima (13·0) Jan. 6, Nov. 4	P.
nis	9·0	11 3 36	83 47	February 9, August 28 ...	W.
iæ	8·0	11 57 4	70 26	October 1	W.
ginis	6·5	12 31 24	82 14	Jan. 1, May 27, Oct. 19 ...	A.
. Maj.	7·5	12 37 48	28 8	April 10, Nov. 22. Minima (12) Jan. 2, Aug. 15	P.
ginis	7·5	12 44 0	83 41	July 28	W.
ginis	7·0	13 20 36	92 28	March 16, November 23 ...	P.
dræ	4·0	13 22 4	112 33	Not until February 1863 ...	B.

Star.	Probable Mag.	Mean Place, 1861. R.A. h m s	N.P.D. ° ′	Times of Maxima.	Authority.
S Virginis	6·0	13 25 42	96 28	May 21. Minimum (11·3) Nov. 17	P.
R Boötis	8·0	14 31 1	62 39	February 16, September 29 ...	W.
S Serpentis	8·0	15 15 7	75 11	March 5	A.
R Coronæ	6·2	15 42 49	61 25	About November. Very irregular	B.
R Serpentis	6·5	15 44 15	74 26	August 29	A.
R Libræ	9·0	15 45 40	105 49	April. Uncertain	P.
R Herculis	8·5	15 59 56	71 15	Oct. 24	B. & W.
R Scorpii	9·0	16 9 19	112 35	April 22. Uncertain ...	P.
S Scorpii	9·5	16 9 20	112 33	April 19. Very irregular ...	—
S Ophiuchi	9·3	16 26 12	106 52	August 5	—
S Herculis	7·5	16 45 32	74 49	September 15	B.
R Ophiuchi	8·0	16 59 44	105 54	June 25	P.
α Herculis	3·0	17 8 16	75 27	Mar. 11, May 16, July 21, Sept. 26, Dec. 1	A.
T Herculis	7·9	18 3 48	59 0	March 16, August 23 ...	K.
R Scuti	5·0	18 40 1	95 50	March 21, May 31, Aug. 11, Oct. 26	A.
13 Lyræ	4·3	18 51 4	46 14	March 18, May 3, June 18, Aug. 3, Sept. 18, Nov. 3	B.
R Aquilæ	6·5	18 59 38	81 59	May 13	A.
R Sagittarii	8·2	19 8 28	109 33	May 19	P.
S Sagittarii	10·5	19 11 14	109 16	December. Very uncertain ...	P.
R Cygni	8·0	19 33 4	40 7	Nov. 14. Minimum (14·5) June 12	P.
χ Cygni	5·0	19 45 11	57 27	June 10	A.
R Capricorni	9·5	20 3 28	104 41	September 25	W.
R Sagittæ	8·4	20 7 40	73 42	Minima (10·5) May 6, July 16, Sept. 25, Dec. 5	B.
S Delphini	8·2	20 36 38	73 25	May 4	B.
U Capricorni	10·5	20 40 22	105 18	April. Uncertain	P.
R Vulpeculæ	8·0	20 58 10	66 44	March 8, July 16, Nov. 23 ...	W.
T Capricorni	9·0	21 14 13	105 45	July 26	S.
R Pegasi	8·5	22 59 37	80 14	April 28	A.
R Aquarii	7·0	23 37 15	106 3	June 28	—
R Cassiopeiæ	6·0	23 51 18	39 23	Nov. 15. Minimum (13) May 30	P.

The preceding Ephemeris has been hastily prepared, chiefly from the elements of variation employed for the last two years.

Mr. Baxendell has as usual favoured me with the maxima of the stars bearing his initial. The minima of the Short Period Variable Stars shall follow by the next mail.

One star, S *Sagittarii*, was discovered at Dr. Lee's Observatory shortly before my departure from England, and has been re-observed here this year. Time forbids further details in this letter.

Madras Observatory, 1861, *Dec.* 28.

On the Stars R *Vulpeculæ and* U *Geminorum, and on an Appearance in Venus.* By G. Knott, Esq.

R *Vulpeculæ*. A few months ago I had the honour of submitting to the Astronomical Society a short paper on an unexpected *minimum* of this star; further observation enables me to report a *maximum*, mag. = 8·7, on or about the 31st December last. It will be seen that this result does not accord with the predictions of Mr. Pogson's valuable Ephemeris; by reference, however, to a paper by Dr. Winnecke, in No. 1224 of the *Astronomische Nachrichten*, it appears that the period is subject to considerable irregularity, for while two observed maxima in 1859 gave a period of 129 days, one of 147·35 days was found more satisfactorily to represent the earlier observations, including two by Piazzi in the beginning of the century. It would be premature on my part to say anything decidedly on this point, I will merely add that my own light-curve seems to favour the shorter period.

U *Geminorum*. This remarkable star was due at maximum on Jan. 21; my own observations show that the maximum actually occurred nineteen or twenty days earlier. On turning my Equatoreal to the spot on the evening of Jan. 3d, I found the star of the 9·4 mag., by the next evening it had fallen to 9·6, and on the 11th of the same month it shone as a star of the 11·2 mag. Bad weather and bright moonlight prevented further observation. Unfortunately the maximum was passed before my observations commenced, but we may probably assume the 1st or 2d of January as the date of its occurrence.

Readers of the *Monthly Notices* will remember an interesting paper by Mr. Pogson (*Monthly Notices*, vol. xx., p. 37) containing an account of a series of observations of this star by M. Goldschmidt in November 1859, from which, in combination with one of his own, he deduced a maximum on Nov. 12th, "full 27 days before the time indicated by computation." Starting from this date, and applying Mr. Pogson's period of 96·879 days, I find a maximum due on Dec. 25th, 1861, a result, which, compared with my own observations, seems to

show that, in the interval, the period has not been subject to any startling irregularity.

I take the opportunity of mentioning a recent observation of that curious phenomenon connected with the planet *Venus*, sometimes called the *phosphorescence of the dark side.* On the evening of Jan. 14th, my uncle, Mr. Berry of Liverpool, was examining the planet with a small but very perfect Gregorian reflector of 4 inches aperture, mag. power 160. The wind was high, but the atmosphere very clear, and in repeated intervals of quiet, when the cusps were sharply defined, the unillumined part of the disk shone with a faint light similar in appearance to the *lumière cendrée* in the crescent Moon. In proof of the independence of the observation I may say, that, at the time, it had entirely escaped Mr. Berry's memory that the phenomenon had been remarked by previous observers.

Woodcroft, Cuckfield, March 10th, 1862.

Orbit of ξ Ursæ Majoris, determined from the Observations made between 1819·10 *and* 1860·08. By J. Breen, Esq.

Perihelion	1816·32
Period	63·14 years.
Excentricity	0·3929
Major semiaxis	2″·454
	° ′
Perihelion from node	132 53
Node	97 18
Inclination	52 16

Comparison of Observed and Calculated Places.

Date.	Angle of Position. [O − C]	Distance. [O − C]	Observer.
	° ′	″	
1819·10	+1 4	(+0·991)	Struve
1826·20	+2 28	+0·007	,,
1831·08	−2 7	+0·157	Bessel
1835·41	+3 11	−0·112	Struve
1840·40	+1 36	+0·055	,,
1843·48	−1 5	+0·235	Bessel
1848·32	−0 19	+0·028	J. Breen
1852·20	+1 18	−0·074	Fletcher
1857·40	+1 14	−0·081	,,
1860·08	+0 58	−0·168	Lord Wrottesley.

Compared with the observations of Sir W. Herschel of 1781·97, and the single measurements of 1802·09 and 1804·08, the calculated angles of position are respectively 5° 42′, 5° 17′, and 6° 21′ in defect.

New Determination of the Longitude of the Sydney Observatory, by means of Thirty-three Moon-Culminations at Greenwich and Sydney, and Twenty-three at the Cape of Good Hope and Sydney. By W. R. Scott, Esq., Astronomer for New South Wales.

	h	m	s
Assumed Longitude of Sydney Observatory	10	5	0
Cape of Good Hope ,,	1	13	55

Greenwich Date.	Correction.	Greenwich Date.	Correction.
	s		s
1860, Jan. 4	−18·90	1860, July 3	−10·13
9	16·17	6	2·90
Mar. 1	16·56	30	16·13
Apr. 2	15·79	Oct. 5	15·42
4	12·39	Nov. 1	13·71
6	4·59	2	8·36
7	10·43	22	14·26
9	12·32	Dec. 22	8·87
30	17·65	1861, Jan. 24	14·94
May 1	15·56	28	19·27
2	15·36	Mar. 22	6·56
3	12·98	23	13·02
4	12·96	Apr. 24	15·99
28	17·01	May 17	18·96
June 25	13·34	22	10·78
26	14·33	July 15	−14·48
30	− 7·60		

Cape of Good Hope.

Greenwich Date.	Correction.	Greenwich Date.	Correction.
	s		s
1859. July 9	−22·53	1859, Oct. 5	−17·28
18	9·40	8	33·97
22	8·81	12	12·92
23	9·14	13	15·02
Aug. 11	9·85	14	14·40
12	12·99	17	14·28
13	14·11	Nov. 3	11·89
19	18·15	4	13·91
Sept. 9	20·79	Dec. 5	15·59
13	19·22	8	22·20
17	9·78	14	−14·37
19	−17·53		

	s
Mean of Corrections from Greenwich Observations	−13·26
,, ,, from Cape of Good Hope ,,	−15·75
Mean of all with Equal Weights	−14·21

Resulting Longitude of Sydney Observatory, $10^h\ 4^m\ 45^s{\cdot}79$

On Comet II., 1861, and on some other Comets. By Dr. Mackay.

(*Communicated by Prof. C. P. Smyth.*)

The Rev. Dr. Mackay, Missionary, Chinsurah, Bengal, has communicated through Prof. C. Piazzi Smyth, his (Dr. Mackay's) observations of the Comet II., or the Great Comet, 1861, and his computation of two sets of elements of the orbit, as follows,—

Ascending Node	279° 2′	278° 59′ 30″
Inclination	85° 33′	85° 29′ 32″
Perihelion dist.	·825	·8267
,, long.	249° 38′	249° 51′
,, passage	June 11^{d} 20^{h}	June 11^{d} 23^{h}

Motion direct.

The first was computed from his own observations of 1861, July 5, 10, 15, and was published in India on July 25th; the second one was computed in August, substituting a French observation of June 30th, printed in the *Journal des Debats*, for the first of his own observations.

The observations are remarkable instances of what may be done with "a sextant and an old ship's chronometer." The Doctor writes, "My plan of observing was, to take every available evening a series of the Comet's distances from *Vega* and *Arcturus*, as near as possible to a mean of 9^{h} 5^{m} 33^{s}, Chinsurah Mean Time (3^{h} 12^{m} G.M.T.), and from these to compute the Comet's Right Ascension and Declination. With the found Right Ascension and Declination I computed its distance from a third star, η *Ursæ Majoris*, which I also measured; and it was only when the computed and observed distances agreed, or slightly differed, (say 1′) that I considered the night's work good.

"In October 1858, with the same sextant, but with better eyesight and longer intervals (6th, 18th, and 30th), I found the elements of the Comet of 1858,

	° ′
Perihelion long.	37 4
,, dist.	·5753
,, passage	Sept. 29^{d} 18^{h} 21^{m}
Long. ascending Node	165° 15′
Inclination	63° 39′

Motion retrograde.

"These were published in the *Friend of India*, about a month before receiving the European determination, thus,

Perihelion long.	36° 13′
" dist.	·579
" passage	Sept. 29^d 23^h
Longitude of Node	165° 19′
Inclination	63° 2′

Motion retrograde."

The following is the Doctor's printed local communication, published in the *Friend of India*, July 25, 1861, which, amongst other interesting particulars, contains his identification of the Comet with Comet I., 1781, computed by Mechain.

"With very considerable labour, by three reduced sextant observations of July 5th, 10th, and 15th, I have computed the following elements for the Comet. They can be considered only as approximate, as my sight is failing, and the intervals rather shorter than I could wish:—

Perihelion long.	249° 38′
" dist.	·825
" passage	June 11^d $20^h{\cdot}7$
Long. ascending Node	99° 1′
Inclination	85° 33′

Motion direct.

"This differs considerably from Hind's May elements, as given in my former letter; but with an orbit almost perpendicular to the ecliptic, such differences are to be expected.

"From these elements I find that the Comet on the evening of July 5th was only eleven millions of miles from the Earth. Probably (for I have not calculated it) it was not much more than five millions, about the beginning of the month. This will account satisfactorily for its immense tail, and great velocity. I should be very thankful for any observations before the 5th and after the 15th. A week or two more will bring the determination from Europe of what the elements really are.

"Hind gives a group of four comets, with large inclinations, direct motions, and perihelion distances varying from ·7 to ·8, ·9, and 1, for which periods have been computed of about 75 years. Another will now be added to the group; for I have no doubt that this comet is identical with the 1st of 1781, of which the elements were found by Mechain.

"They are as follows:

Perihelion long.	239°	Hind has 243
,, dist.	·755	
,, passage	July 7^d	
Ascending Node	83°	
Inclination	81°	
	Motion direct.	

If so, a comet with a known period of 80 years will take rank with Halley's. If they could be found, it would be interesting to recompute Mechain's calculations.

"On looking through Hind's list, I find a Comet in 1797 not very unlike, and another in 68 B.C., which I feel strongly disposed to identify with our Comet. From the obscure notices of the period in the Chinese annals, it appears to have had a perihelion distance of 8, and an inclination of 70°. Adding 68 to 1861, we have 1929, a near enough multiple of 80, when it is considered how much the cometary periods vary.

"No doubt all this has been discovered, and much more satisfactorily, in Europe; but it is new at least in this country.

"W. S. M."

"*Chinsurah, 19th July*, 1861.

"My observations were,—

		R.A.	N. Decl.
	h m	° ′ ″	° ′ ″
July 5	3 12	172 31 30	66 40 20
10	3 12	206 10 15	59 41 17
15	3 12	215 41 0	54 50 32

The time is Greenwich mean time."

Extract of a Letter from Mr. Lassell.

(*Communicated by Prof. De Morgan.*)

"The principal work, however, I have hitherto done is the perfectly successful erection of the four-foot Equatoreal, on a most favourable site near Fort Tigné, on the north side of the Quarantine Harbour in this island. It differs a little from the lithographic drawing in the possession of the Society, as it is now erected in the latitude for which it was constructed, and not, as in that sketch, with the polar axis inserted in an excavation, to allow of its temporary use in the latitude of Liver-

pool. It is, indeed, much more substantially erected, with a view to its permanent efficiency in this far more favourable climate, where I trust it will do all that can reasonably be expected from 48 inches of aperture. I am glad to say that I have had no accident whatever in the erection, nor in the transmission of the mirrors, that which is now in the tube, after the dissolution and removal of its coat of varnish, having come out as fine in lustre as if it had been polished only yesterday.

"I have hitherto only cursorily examined a few objects, some of the minor conveniences of the apparatus not being yet quite completed; but I see enough to convince me that I have now a much more powerful and efficient telescope than I have ever possessed before. We are now passing through the most unsettled portion of the year, and I have found this so-called winter less favourable for the use of a large telescope than the same portion of the year 1852; I can, therefore, scarcely tell what the telescope will do under the most favourable circumstances. In turning it, however, upon the Nebula in *Orion*, I see so much more of its wonderful constitution, that I feel very ill-satisfied with my former drawings, and must begin anew. I was, indeed, at first rather surprised, perhaps disappointed, not to see many more new stars; but, on reflection, I am inclined to think this may be satisfactorily accounted for by the great increase of brightness of the Nebula rendering the eye less sensible to very minute points of light. And this view is confirmed by observations of stars in the day-time with the transit instrument, which, I suppose from the greater light of the sky here, are scarcely so visible as in England.

"The fainter and interior satellites of *Uranus*, *Umbriel* and *Ariel*, though as much inferior in brightness to what have been called the bright satellites, as *Rhea*, or even *Dione*, among the satellites of *Saturn*, is to *Titan*, are conspicuous objects; and, with a magnifying power of 1060, not to be overlooked on any tolerable night. If *Uranus* has any other satellites than these, they must be very much smaller or fainter.

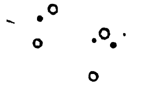
"The only indication of *Saturn's* ring at present visible is its shadow as a thin, hard, dark, rough line across or along the equator of the planet, which is now so full of sharp belts over almost all its surface, that it might be taken for a view of *Jupiter* with a smaller telescope. On the 25th instant all the satellites but *Japetus* were in the field of view at once; *Mimas* and *Enceladus* within a very few seconds, indeed, of the limb of the planet; the latter almost touching it. Another of the nearer satellites emerged from behind the preceding limb during observation.

"P. S.—It is, perhaps, scarce worth mentioning, and yet it struck me as either a fortunate coincidence or an evidence of care, that I have had no occasion to touch the adjustments of either Right Ascension or Polar Distance since the telescope was

first directed to a celestial object; and, without having made any observations expressly for the purpose, I have not been made aware of any obvious error, in turning the telescope upon such objects as I have examined.

"9 *Piazza Slierna, Malta, 28th January,* 1862."

And, in a letter dated the 30th January, Mr. Lassell writes,—"The detention of the mail allows me to add a postscript to my letter of yesterday, to inform you of my having discovered, last night, a new star within the trapezium in the great Nebula of *Orion*. It is situated near *Theta*, the principal star; appears to be about a full magnitude less than that known as 'the sixth star;' and is about one sixteenth of its distance from *Theta*. Its angle of position from *Theta* is about 100° less than that of 'the sixth star;' and, consequently, points a little eastward of the star at the opposite angle of the trapezium. For verification I annex a diagram.



"I suspect that the position-angle of 'the sixth star' has considerably increased since 1852."

Results of Meridional Observations of Small Planets; Occultation of a Star by the Moon; and Phenomena of Jupiter's Satellites; observed at the Royal Observatory, Greenwich, during the months of January and February, 1862.

(*Communicated by the Astronomer Royal.*)

Metis ⑨.

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, Jan. 16	13 25 54·4	9 10 46·25	64 58 1·11
22	12 56 31·4	9 4 57·79	64 17 28·31
24	12 46 36·6	9 2 54·52	64 4 35·41
25	12 41 37·8	9 1 51·44	63 58 19·81
27	12 31 39·3	8 59 44·39	63 46 12·19
28	12 26 39·7	8 58 40·53	63 40 17·65
Feb. 3	11 56 40·3	8 52 15·56	63 8 28·38
7	11 36 48·6	8 48 6·80	62 50 58·54
10	11 22 2·0	8 45 7·42	62 39 54·42

Eunomia (15).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, Jan. 25	12 16 36·2	8 36 45·72	75 52 24·27
27	12 6 36·0	8 34 36·92	75 53 2·04
Feb. 10	10 57 31·8	8 20 33·16	75 55 8·66
18	10 19 32·5	8 14 0·05	75 56 19·34

Thalia (23).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, Feb. 18	12 53 43·6	10 48 36·56	61 32 23·96

Calypso (53).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, Feb. 10	12 42 14·8	10 5 33·35	77 55 8·14

All the observations of N.P.D. have been corrected for refraction and parallax.

The disappearance of *d Geminorum*, on 1862, Jan. 14, at the Moon's dark limb was observed by Mr. Carpenter to take place at $6^h\ 29^m\ 58^s{\cdot}9$ G.M.T. The star was extremely faint.

Phenomena of Jupiter's Satellites.

Day of Observation.	Satellite.	Phenomenon.	Mean Solar Time.	Observer.
1862.			h m s	
Jan. 24	IV	Occ. reapp. last cont.	14 35 0·4	C.
28	I	Eclipse, disapp.	12 52 48·0	E.
Feb. 18	IV	Egress, first cont.	11 12 36·9	S.
,,	IV	,, last cont.	11 17 17·2	S.
,,	III	Occ. reapp. first cont.	11 53 45·2	S.
,,	III	,, last cont.	12 2 6·9	S.

Feb. 18, The image of the planet exceedingly tremulous, and sometimes faint from cloud.

The initials S., E., C., are respectively those of Mr. Stone, Mr. Ellis, and Mr. Criswick.

Occultation observed at Highbury. By T. W. Burr, Esq.

1862, January 4th. The star *κ Aquarii* disappeared at the dark limb of the Moon, at $1^h\ 34^m\ 49^s{\cdot}6$ local sidereal time, $= 6^h\ 38^m\ 47^s{\cdot}1$, Greenwich mean time. This occultation was instantaneous, but there had been a disappearance and reappearance about a minute previously, of an abnormal character. The Moon's dark limb was visible, and approaching the star extinguished it at $1^h\ 33^m\ 12^s{\cdot}6$ L.S.T. After watching some little while, to be sure of the fact, I verified my time and recorded the observation, but on returning to the telescope was surprised to see the star again visible close to the Moon's edge, and finally disappearing as above mentioned. This is the only occasion out of the many occultations I have witnessed when anything unusual has occurred, but the observation in this case may be relied on.

The ultimate reappearance was not seen, owing to a passing cloud.

The time was checked by transits of *α Andromedæ* and *β Ceti*, corrected by Mr. Epps' tables (*Mem. Ast. Soc.* vol. iv.). Telescope, focal length, 4 ft. 4 in. Aperture, $3\frac{3}{8}$ in. Power, 173. Longitude, 24^s W.

March 10, 1862.

Solar Eclipse of 31*st December*, 1861, *observed at Goree, and at St. Louis, Senegal, by Officers of the French Imperial Navy.*

By authority of the Duke of Newcastle, Secretary of State for the Colonies, Mr. Hind communicated to the Society the original of the Report of these observations, taken by the direction of the Governor of the French colony of Senegal; Mr. Hind states that the observations are due to the warm interest evinced by Capt. Washington, the Hydrographer of the Admiralty, on the occasion: he having forwarded a few instructions drawn up by the Astronomer Royal to the Governor of the Gambia, with a request that he would procure from the authorities at Goree a report of the eclipse.

The observers at St. Louis were MM. Vallon, Ribel, and De Marteville; those at Goree, MM. Poulain and Dutaillis. The eclipse commenced at St. Louis about $0^h\ 4^m$, and the last contact was observed at $2^h\ 57^m\ 36^s{\cdot}1$. At Goree the Moon had entered about one-tenth of the diameter on the solar disk at $0^h\ 3^m\ 35^s$, and the eclipse terminated at $2^h\ 51^m\ 18^s$.* For

* The times throughout are mean solar time of St. Louis or of Goree, according to the place of observation.— Ed.

want of a telescope of sufficient power the red prominences were not observed at Goree. The following are extracts from the Report:—

"*Saint Louis.*—A $1^h\ 30^m\ 50^s$ pendant que le croissant du Soleil passe rapidement à l'occident de la Lune, une magnifique protubérance se détache du coté opposé à 12° environ au-dessus du diamètre horizontal du Soleil. D'abord voisine de la corne supérieure orientale, sa base en partie cachée par la Lune embrasse 5 ou 6 dégrés du disque solaire; le sommet, éclairé d'un beau rose, se dessine franchement sur une portion de couronne d'aspect rayonnant, jetant quelques ombres très mobiles qui descendent du nord au sud comme le feraient les ailes rapides d'un moulin à vent. Ces rayons d'ombre convergent au centre du Soleil.

"Ce beau phénomène dure de $1^h\ 30^m{\cdot}50$ à $1^h\ 34^m\ 44^s$, heure à laquelle la protubérance et tout jeu de lumière s'effacent derrière le disque de la Lune. Cette protubérance étant très voisine de la perpendiculaire à la corde du croissant solaire, son immersion a été suivie avec soin. La base à d'abord disparu, puis graduellement toutes ses parties, dans le tems du mouvement de l'éclipse; enfin le sommet, au moment ou l'épaisseur du croissant était mesurée au cercle $1'\ 10''$.

"Il est évident que cette mesure correspond à peu près exactement à la hauteur du sommet de la protubérance sur le disque du Soleil, auquel elle est *sans nul doute* attachée, ces deux éléments étant situés aux extrémités d'un même diamètre.

"Nous croyons que la protubérance est l'effet d'un amas de nuages solaires; le telescope permettait d'en compter les dentelures au nombre de trois principales sur son versant supérieur. La partie inférieure moins étendue paraissait en surplomb sur le bord de la Lune. Le sommet, mieux éclairé que la base, dont la Lune masquait le lieu de jonction au disque solaire, atteint son maximum d'éclat, une minute avant son immersion.

"*Gorée.*—Faute de téléscope, on ne peut que reconnaître le beau phénomène de la couronne qui environne les disques superposés au point de produire l'effet d'une éclipse annulaire.

"*Saint Louis.*—La portion de couronne visible à l'orient de la Lune embrassait un secteur de 60 à 70 dégrés. D'un beau rose près des disques des astres, les rayons allaient s'affaiblissant dans la teinte sombre du ciel. Sa structure était à rayons, et elle a paru suivre l'immersion graduelle de la protubérance.

"La lumière de cette portion de couronne a été observée à éclat; effet produit par les ombres rapides que nous avons signalées plus haut.

"*Gorée.*—Vers $1^h\ 25^m$ on voit des franges noires se dessiner sur le mur de la terrasse d'observation: à $1^h\ 26^m$ l'éclipse paraît centrale; une cercle lumineux existe autour du disque lunaire; son épaisseur est de $\frac{1}{3}$ de doigt; des aigrettes lumineuses émanent de tous cotés; à droite et à gauche elles sont

parfaitement symétriques ; au-dessus, il y en a une plus longue et plus large ; au-dessous elles sont plus courtes.

"Il règne dans les environs une obscurité qu'on peut comparer à la lueur d'un crépuscule dans les plus belles régions de l'Europe. *Vénus* et trois autres étoiles paraissent au firmament à $2^h 34^m 30^s$; la distance de *Vénus* au Soleil a été observée $46^\circ 30'$.

"*Saint Louis.*—Trois groupes de taches ont paru dans le 2e quartier du Soleil, deux autres plus petits à la partie inférieure du 4e quartier.

"Ces taches ont en général un noyau brun dont les bords sont *tranchés* sur l'enveloppe vaporiforme qui la circonscrit. Cette enveloppe, d'une teinte neutre affaiblie, a un contour bien accusé sur le disque du Soleil.

"Nous affirmons que pendant la durée de l'observation aucune de ces taches n'a changé de position relative, de forme absolue, ni de teinte.

"Doivent-elles leur existence au déchirement de la photosphère qui laisserait apercevoir le noyau central du Soleil, ou son enveloppe de nuages obscurs, suivant Arago ? Cette explication satisfait pleinement la vue. Sont-elles le résultat d'une accumulation de nuages solaires de même nature que les protubérances? Cette dernière supposition fort ingénieuse ne nous paraît cependant pas soutenable, et n'explique ni la figure étrange des taches, ni leur immobilité pendant 3 heures, ni enfin la permanence des effets de l'éclairage de toutes leurs parties.

"Le centre des taches principales renfermait des espaces lumineux disposés irrégulièrement. La Lune, dans son ascension, a successivement recouvert ces groupes; ils devenaient d'autant plus visibles que son disque s'en approchait d'avantage. Aucune de ces taches en s'immergeant, ou en reparaissent, n'a subi la moindre altération de forme. Les cornes du Soleil se sont effilées sans distorsion apparente.

"Les baromètres au moment de la plus grande obscurité sont descendus de 763·5 à 762·5.

"Les thermomètres au Soleil de 34° centigrades à $23^\circ{\cdot}6$.

"Les thermomètres à l'ombre de $28^\circ{\cdot}3$ centigrades à $23^\circ{\cdot}5$.

"L'arguille aimantée n'éprouve aucune oscillation.

"Les deux hygromètres accusent 10 centièmes d'humidité en plus.

"Enfin, la face du Soleil a paru très homogène, à part quelques groupes irréguliers de facules lumineuses qui environnent les deux petits groupes de taches inférieures.

"*Gorée.*—Le thermomètre à l'ombre est descendu de $25^\circ{\cdot}8$ à 20 dégrés. La courbe de la chaleur parait d'accord avec celle de la lumière.

"Le baromètre a varié entre 762 et 763.

"Le psycromètre, formé de deux thermomètres, un sec et un mouillé, donnait en centièmes, au moyen des tables, la

quantité d'humidité renfermée dans l'air. Il a accusé 12 centièmes d'augmentation.

"Le phénomène des franges noires a été observé un instant avant l'occultation; elles avaient, sur une surface verticale dirigée sensiblement de l'ouest à l'est, une direction de 45° par-dessus l'épaule gauche; leur largeur et leur espacement étaient à-peu-près égaux et mesuraient environ 10 centimètres. La nuance était une ombre claire qui a paru dégradée sur les bords.

"Avant et après l'occultation, les animaux domestiques et les plantes ont été influencés comme à l'approche de la nuit et au lever du jour.

"Il y avait à Gorée un raz de marée exceptionnel.

"*Saint Louis.*—*Vénus* a paru dans le S. E. au moment de la plus grande obscurité. Les édifices blanchis à la chaux paraissaient gris jaunâtres. Le rouge conservait sa couleur. La moindre épaisseur du croissant solaire a été mesurée 57″ à $1^h\ 30^m\ 49^s$."

Sir Thomas Maclear has communicated Observations of the Right Ascensions and North Polar Distances of Comet I., 1861, made at the Royal Observatory, Cape of Good Hope, from 18th August to 6th September, 1861; and in a letter, dated 21st December, 1861, addressed to the Astronomer Royal, he writes:—

"Dr. Pape's ephemeris reached the Cape too late. By extending it from August 6th, its limit, the comet was readily found—then too faint, however, for precise work.

"I detected Encke's Comet on the 4th instant, but the light was too feeble for place, and a few days after the moonlight extinguished it altogether. It is now workable, and I hope for a good series of observations.

"It would be well to get up a rough working ephemeris of all the periodic comets several months beforehand, and to circulate them freely. By rough I mean with omission of the perturbation corrections."

The observations will probably be printed, along with those of Comet II., 1860, in the *Memoirs* of the Society.—Ed.

A paper "On Astronomical Refraction," by Mr. Andrew Yeates, was read at the Meeting.

Among the Presents to the Society, there were presented by Mr. H. G. Bohn of York Street, Covent Garden:—

Opusculum Johannis de Sacrobusto Sphericum. Lipsiæ, 4to. *s.a.*

Ditto. Liptczk, 4to. 1499; with additional matter in manuscript.

Flores Albumasaris, Ehrhardt Ratdolt. 4to. 1495. At the end there are about 22 pages of Astrological matter, beautifully written in a monastic or court hand.

Discovery of a Companion of Sirius.

In the *Ast. Nach.*, No. 1353, Prof. Bond communicates the discovery of a Companion of *Sirius*, made on the evening of Jan. 31 by Mr. Clark, with his new object-glass of 18½ inches aperture. Prof. Bond was able to observe it with the Refractor of 15 inches, at the Observatory of Harvard College, as follows:

1862, Feb. 10,	Angle of Position	$85^\circ\ 15$	$\pm 1^\circ\ 1$
	Distance ...	$10''\cdot37$	$\pm 0''\cdot2$

when the images were tranquil, the Companion was seen distinctly enough, but on account of the atmospheric disturbances these moments are quite rare.

The Companion was seen at Paris by M. Chacornac, the 20th March, with the telescope with silvered mirror of 80 centimeters, constructed according to the plans and under the direction of M. Foucault.

It appears from the *Cosmos* of 28th March, that Dr. Peters does not accept the identity of the Companion thus discovered with that which he had calculated.

Discovery and Elements of a New Minor Planet, (72).

In the *Ast. Nach.*, No. 1353, Prof. Bond communicates also the discovery of this new Minor Planet, under the following circumstances. Mr. Safford having had occasion to refer to the positions of *Maia* (66), obtained by Dr. Peters at Hamilton

College, and published in Brünnow's *Astronomical Notices*, No. 20, was surprised to find that only three of the series, namely, the places for 1861, May 9, 11, and 12, could be reconciled with the Cambridge (U.S.) observations. A reference to Mr. Hall's Ephemeris of *Maia* (*Ast. Nach.*, No. 1315), showed that the Ephemeris represented the Cambridge observations of *Maia* from April 9 to May 27, nine in number, and also the first three of those of Dr. Peters, but that it did not represent the later observations of Dr. Peters. It was at once conjectured that in the interval between May 12 and May 29, when clouds and moonlight intervened to prevent a close following of *Maia*, which was only of the 13th mag., Dr. Peters had lost its trace, and on resuming his observations had fallen on a new Planet. Mr. Safford, after obtaining corrected positions of the comparison stars of Dr. Peters, obtained the following elements,—

1861, May 29·375 Washington M.T.

$$\left.\begin{array}{ll} L & = 213^\circ\ 3'\ 24''\cdot 1 \\ \varpi & = 329\ \ 22\ \ 16\cdot 5 \\ \Omega & = 208\ \ \ 1\ \ 28\cdot 0 \end{array}\right\}\text{ Mean Equinox 1861·0}$$

$$\begin{array}{ll} i & = \ \ 5\ \ 23\ \ 16\cdot 2 \\ \varphi & = \ \ 6\ \ 50\ \ 26\cdot 0 \\ \mu & = 1129''\cdot 372 \\ \log a & = 0\cdot 331446 \end{array}$$

It is noticed that (72) has the least mean distance yet recognised among the Minor Planets.

RECENT PUBLICATION.

A Handbook of Descriptive and Practical Astronomy. By Geo. F. Chambers, F.R.G.S. 8vo. London, 1861.

The author remarks that his book is intended to occupy a middle position between purely elementary books on the one hand, and advanced treatises on the other hand; to be attractive to the general reader, useful to the amateur, and "handy" also as an occasional book of reference to the professional astronomer. Pains have been taken to incorporate the most recent discoveries in all branches of the science, and the Work appears to be very complete in its range of subjects; and in general to be fully entitled to take up the position claimed for it by the author. The chronological tables of Astronomers and of Discoveries in Book 9, and the tables of Eclipses, Comets, Star Catalogues, &c., contained in the Appendices, will probably be found useful for reference.

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Printed by STRANGEWAYS and WALDEN, Castle St. Leicester Sq. and Published at the Apartments of the Society, April 10, 1862.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXII. *Supplemental Notice.* No. 5 *bis.*

*On the Secular Acceleration of the Moon's Mean Motion.**

By A. Cayley, Esq.

The present Memoir exhibits a new method of taking account, in the Lunar Theory, of the Variation of the Excentricity of the Sun's Orbit. The approximation is carried to the same extent as in Prof. Adams' Memoir "On the Secular Variation of the Moon's Mean Motion" (*Phil. Trans.*, vol. cxliii. (1853), pp. 397–406); and I obtain results agreeing precisely with his, viz., besides his new periodic terms in the longitude and radius vector, I obtain in the longitude the secular term

$$\left(-\frac{3}{2}m^2 + \frac{3771}{64}m^4\right)\int\left(e'^2 - E'^2\right)n\,dt,$$

and in the quotient radius, or radius vector divided by the mean distance, the secular term

$$\left(\frac{3}{4}m^2 - \frac{1973}{64}m^4\right)\ \left(e'^2 - E'^2\right),$$

which is, in fact, as will be shown, included implicitly in the results given in Professor Adams' Memoir. In quoting the foregoing results, I have written $e'^2 - E'^2$ in the place of $(e' + f't)^2 - e'^2 = 2e'f't$, which in the notation of the present Memoir it should have been; and I purposely refrain from here explaining the precise signification of the symbols: this is carefully done in the sequel. The method appears to me a very simple one in principle; and it possesses the advantage that it is not incorporated step by step with a lunar theory in which the

* This Memoir, an abstract of which appeared in the December number, p. 32, has been ordered by the Council to be printed *in extenso*.—Ed.

excentricity of the Sun's orbit is treated as constant; but it is added on to such a lunar theory, giving in the Moon's coordinates the supplementary terms which arise from the variation of the solar excentricity, and thus serving as a verification of any process employed for taking account of such variation.

I have given the details of the work in a series of Annexes, 1 to 23: this appears to me the best course for presenting the investigation in a readable form.

I.

The inclination and excentricity of the Moon's orbit, and, *à fortiori*, the variation of the position of the Ecliptic, and the Sun's latitude, are neglected; and the longitudes are measured from a fixed point in the Ecliptic. I write

n, the actual mean motion of the Moon at a given epoch;

viz., it is assumed that the mean longitude at the time t is $\varepsilon + n\,t + n_2\,t^2 +$ &c. where ε, n, n_2, &c. are absolute constants; and, moreover,

a, the calculated mean distance of the Moon;

that is, $n^2 a^3$ is the sum of the masses of the Earth and Moon; a is therefore an absolute constant; and, in like manner,

n', the actual mean motion of the Sun at the same epoch,

a', the calculated mean distance of the Sun;

that is, if it were necessary to pay attention to the secular variation of the mean motion of the Sun, the assumption would be that the mean longitude was $\varepsilon' + n'\,t + n'_2\,t^2 +$ &c., ε', n', n'_2, &c. being absolute constants, and $n'^2 a'^3$ the sum of the masses of the Sun and Earth; a' would thus also be an absolute constant. But for the purpose of the present investigation the secular variation of the mean longitude of the Sun is neglected, or it is assumed that the mean longitude of the Sun is $\varepsilon' + n'\,t$, ε', n' being absolute constants; and that $n'^2 a'^3$ is the sum of the masses of the Sun and Earth, a' being thus also an absolute constant.

I put also

m, the ratio of the mean motions of the Sun and Moon;

that is,

$$m = \frac{n'}{n}, \text{ or } n' = m\,n;$$

m is also an absolute constant.

The Sun is considered as moving in an elliptic orbit, the excentricity whereof is $e' + \delta e'$ or $e' + f' t$, e' and f' being absolute constants; the longitude of the Sun's perigee may be taken to be $\varpi' + (1 - c') n' t$; so that the mean anomaly g' is $= n' t + \epsilon - [\varpi' - (1 - c') n' t] = c' n' t + \epsilon' - \varpi'$; c', ϖ', being absolute constants; but c' is in fact treated as being $= 1$. Hence, if r', v' are the radius vector and longitude of the Sun, we have

$$r' = a' \operatorname{elqr} (e' + \delta e', g')$$

$$v' = \varpi' + (1 - c') n' t + \operatorname{elta} (e' + \delta e', g')$$

$$= n' t + \epsilon + [\operatorname{elta} (e' + \delta e', g') - g'],$$

where

$$g' = c' n' t + \epsilon' - \varpi'.$$

In the expression for the disturbing function the Sun's mass is taken to be $= n'^2 a'^3$, or, what is the same thing, $= m^2 n^2 a'^3$.

Let r, v be the radius vector and longitude of the Moon; then, taking the usual approximate expression of the Disturbing Function, the equations of motion are

$$\frac{d}{dt} \frac{dr}{dt} - r \left(\frac{dv}{dt}\right)^2 + \frac{n^2 a^3}{r^2} = m^2 n^2 a'^3 \frac{r}{r'^3} \left(\frac{1}{2} + \frac{3}{2} \cos 2v - 2v'\right),$$

$$\frac{d}{dt} \frac{r^2 dv}{dt} = m^2 n^2 a'^3 \frac{r^2}{r'^3} \left(-\frac{3}{2} \sin 2v - 2v'\right);$$

It will be convenient to assume

ρ, the quotient radius of the Moon's orbit,

ρ', the quotient radius of the Sun's orbit;

that is

$$r = \rho a, \quad r' = \rho' a'.$$

The equations of motion thus become

$$\frac{d}{dt} \frac{\delta \rho}{dt} - \rho \left(\frac{dv}{dt}\right)^2 + \frac{n^2}{\rho^3} = m^2 n^2 \mathrm{P},$$

$$\frac{d}{dt}\left(\rho^3 \frac{dv}{dt}\right) = m^2 n^2 \mathrm{Q},$$

where for shortness

$$\mathrm{P} = \frac{\rho}{\rho'^3}\left(\frac{1}{2} + \frac{3}{2} \cos 2v - 2v'\right),$$

$$\mathrm{Q} = \frac{\rho^2}{\rho'^3}\left(-\frac{3}{2} \sin 2v - 2v'\right),$$

in which

$$\varrho' = \text{elqr}\,(e' + \delta e', g')$$
$$v' = n't + \iota' + [\text{elta}\,(e', g') - g']$$

I now change the notation by writing $\varrho' + \delta\varrho'$, $v' + \delta v'$, in the place of ϱ', v', respectively, using henceforward ϱ', v' to denote

$$\varrho' = \quad \text{elqr}\,(e', g')$$
$$v' = n't + \iota' + [\text{elta}\,(e, g') - g'];$$

and I write also $\varrho + \delta\varrho$, $v + \delta v$, in the place of ϱ, v, using henceforward ϱ, v to denote the solutions of the equations obtained from the equations of motion by writing therein ϱ', v' instead of the complete values $\varrho' + \delta\varrho'$, $v' + \delta v'$.

Suppose, in like manner, that the complete values of P, Q are denoted by $\text{P} + \delta\text{P}$, $\text{Q} + \delta\text{Q}$, where

$$\delta\text{P} = \frac{d\text{P}}{d\varrho}\delta\varrho + \frac{d\text{P}}{dv}\delta v + \frac{d\text{P}}{d\varrho'}\delta\varrho' + \frac{d\text{P}}{dv'}\delta v',$$

with a like value for δQ, the first powers of $\delta\varrho$, δv, $\delta\varrho'$, $\delta v'$ being alone attended to. Then, observing that the equations of motion are satisfied when $\delta\varrho$, δv, $\delta\varrho'$, $\delta v'$ are neglected, we have, it is clear,

$$\frac{d}{dt}\ \frac{d\delta\varrho}{dt} - \delta\varrho\left(\frac{dv}{dt}\right)^2 - 2\varrho\frac{dv}{dt}\frac{d\delta v}{dt} - \frac{2n^2}{\varrho^3}\delta\varrho = m^2n^2\delta\text{P},$$

$$\frac{d}{dt}\left(\varrho^2\frac{d\delta v}{dt} + 2\varrho\delta\varrho\frac{dv}{dt}\right) \qquad = m^2n^2\delta\text{Q}.$$

The second of these equations gives

$$\varrho^2\frac{d\delta v}{dt} + 2\varrho\delta\varrho\frac{dv}{dt} = m^2n^2(\text{C} + \int d\text{Q}\,dt),$$

where the constant of integration, C, is to be so determined that δv may not contain any term of the form kt (for any such term is taken to be included in the term nt of $v + \delta v$). Multiplying the equation just obtained by $\frac{2}{\varrho}\frac{dv}{dt}$, and adding it to the first equation, we have

$$\frac{d^2\delta\varrho}{dt^2} + \left\{3\left(\frac{dv}{dt}\right)^2 - \frac{2n^2}{\varrho^3}\right\}\delta\varrho = m^2n^2\left(\delta\text{P} + \frac{2}{\varrho}\frac{dv}{dt}(\text{C} + \int d\text{Q}\,dt)\right),$$

which, with the above-mentioned integral equation, are the

equations for the solution of the problem; but it will be convenient to write them under the slightly different form

$$\frac{d^2\delta\varrho}{dt^2}+n^2\delta\varrho=\left\{n^2+\frac{2n^2}{\varrho^3}-3\left(\frac{dv}{dt}\right)^2\right\}\delta\varrho+m^2n^2\left\{\delta P+\frac{2}{\varrho}\frac{dv}{dt}\left(C+\int d\,Q\,dt\right)\right\},$$

$$\frac{d\delta v}{dt}=\qquad -\frac{2}{\varrho}\frac{dv}{dt}\delta\varrho+\frac{m^2n^2}{\varrho^2}\left(C+\int\delta\,Q\,dt\right).$$

In these equations C is determined, as above, by the condition that $\frac{d\delta v}{dt}$ may contain no constant term; the values of ϱ', v', $\delta\varrho'$, $\delta v'$ are of course given by the theory of elliptic motion, and those of ϱ, v are given by the ordinary lunar theory, in which the excentricity of the solar orbit is treated as a constant; and then, $\delta\varrho$, δv being obtained by integrating the equations, the radius vector and longitude of the Moon are $a\ (\varrho+\delta\varrho)$ and $v+\delta v$ respectively.

We have

$$P=\frac{\varrho}{\varrho'^3}\left(\frac{1}{2}+\frac{3}{2}\cos 2v-2v'\right),$$

$$Q=\frac{\varrho}{\varrho'^3}\left(\quad-\frac{3}{2}\sin 2v-2v'\right).$$

Moreover, by the lunar theory, observing that Plana's a is or may be considered identical with the a of the present Memoir, and putting also

$$\tau=nt+\epsilon-(n't+\epsilon'),$$

we have

$$\begin{aligned}
\frac{1}{\varrho}=1+\frac{1}{6}m^2-\frac{3}{4}m^2e'^2 & \\
-\frac{3}{2}m^2e' & \qquad \cos g' \\
+m^2-\frac{5}{2}m^2e'^2 & \qquad ,,\ 2\tau \\
+\frac{7}{2}m^2e' & \qquad ,,\ 2\tau-g' \\
-\frac{1}{2}m^2e' & \qquad ,,\ 2\tau+g' \\
-\frac{9}{4}m^2e'^2 & \qquad ,,\ 2g' \\
+\frac{17}{2}m^2e'^2 & \qquad ,,\ 2\tau-2g' \\
0\,m^2e'^2 & \qquad ,,\ 2\tau+2g',
\end{aligned}$$

$$
\begin{aligned}
v = nt + \epsilon & \\
& - 3\, m e' + 0\, m^2 e' && \sin g' \\
& + \frac{11}{8} m^2 - \frac{55}{16} m^2 e'^2 && \;,, \quad 2\tau \\
& + \frac{77}{16} m^2 e' && \;,, \quad 2\tau - g' \\
& - \frac{11}{16} m^2 e' && \;,, \quad 2\tau + g' \\
& - \frac{9}{4} m e'^2 + 0\, m^2 e'^2 && \;,, \quad 2 g' \\
& + \frac{187}{16} m^2 e'^2 && \;,, \quad 2\tau - 2 g' \\
& \quad 0\, m^2 e'^2 && \;,, \quad 2\tau + 2 g',
\end{aligned}
$$

where the series are carried as far as m^2 and e'^2; the terms in e'^2 are given, as I shall have occasion to refer to them, but they are not used in the investigation, and, omitting them, the values are

$$
\begin{aligned}
\frac{1}{\varrho} = 1 + \frac{1}{6} m^2 & \\
& - \frac{3}{2} m^2 e' && \cos g' \\
& + \quad m^2 && \;,, \quad 2\tau \\
& + \frac{7}{2} m^2 e' && \;,, \quad 2\tau - g' \\
& - \frac{1}{2} m^2 e' && \;,, \quad 2\tau + g',
\end{aligned}
$$

$$
\begin{aligned}
v = nt + \epsilon & \\
& - 3\, m e' && \sin g' \\
& + \frac{11}{8} m^2 && \;,, \quad 2\tau \\
& + \frac{77}{16} m^2 e' && \;,, \quad 2\tau - g' \\
& - \frac{11}{8} m^2 e' && \;,, \quad 2\tau + g'
\end{aligned}
$$

$$(g' = c' m n t + \text{const.}, \quad 2\tau = (2 - 2m)\, n t + \text{const.})$$

For the co-ordinates of the Sun we have

$$
\begin{array}{lll}
\dfrac{1}{\rho'} = & 1 & \\
& + e' & \cos g' \\
& + e'^2 & ,, \ 2g', \\
v' = & n't + \epsilon' & \\
& + 2e' & \sin g' \\
& + \dfrac{5}{4}e'^2 & ,, \ 2g',
\end{array}
$$

the series being carried as far as e'^2; but the terms in e'^2 are only used for the formation of $\delta\rho'$, $\delta v'$; and, omitting them, we have

$$
\begin{array}{lll}
\dfrac{1}{\rho'} = & 1 & \\
& + e' & \cos g', \\
v' = & n't + \epsilon' & \\
& + 2e' & \sin g'.
\end{array}
$$

If $e' + f't$ is written for e', then the value of $\delta e'$ is $= f't$; but as only the terms multiplied by the simple power f' are attended to, we may for convenience write $\delta e' = t$, the factor f' being restored in the final results: we thus have

$$
\begin{array}{lll}
\delta\dfrac{1}{\rho'} = & 1 & t\cos g' \\
& + 2e' & ,, \ 2g', \\
\delta v' = & 2 & t\sin g' \\
& + \dfrac{5}{2}e' & ,, \ 2g',
\end{array}
$$

and we may add the equations

$$
\begin{array}{lll}
\dfrac{dv}{dt} = & \overbrace{1}^{n\times} & \\
& - 3m^2e' & \cos g' \\
& + \dfrac{11}{4}m^2 & ,, \ 2\tau \\
& + \dfrac{77}{8}m^2e' & ,, \ 2\tau - g' \\
& - \dfrac{11}{8}m^2e' & ,, \ 2\tau + g',
\end{array}
$$

$$\begin{aligned}
\delta\frac{1}{\rho'^3} &= 3e' \quad t \\
&+ 3 \quad t\cos g' \\
&+ \frac{9}{2}e' \quad ,, \quad 2g', \\
\frac{\delta v'}{\rho'^3} &= 2 \quad t\sin g' \\
&+ \frac{11}{2}e' \quad ,, \quad 2g',
\end{aligned}$$

which will be found useful.

II.

Proceeding now to the development of the solution, we have

$$\begin{aligned}
\delta P = {} & \frac{1}{\rho'^3}\left(\frac{1}{2} + \frac{3}{2}\cos 2v - 2v'\right)\delta\rho \\
& + \frac{\rho}{\rho'^3}\left(\quad - \frac{3}{2}\sin 2v - 2v'\right)\delta v \\
& + \rho\left[\left(\frac{1}{2} + \frac{3}{2}\cos 2v - 2v'\right)\delta\frac{1}{\rho'^3} + \left(3\sin 2v - 2v'\right)\frac{\delta v'}{\rho'^3}\right],
\end{aligned}$$

where the terms containing $\delta\rho$ and δv are (see Annex 1)

$$\left.\begin{array}{ll}
\frac{1}{2} & \\
+\frac{3}{2}e' & \cos g' \\
+\frac{3}{2} & \quad ,, \quad 2\tau \\
+\frac{21}{4}e' & \quad ,, \quad 2\tau - g' \\
-\frac{3}{4}e' & \quad ,, \quad 2\tau + g'
\end{array}\right| \delta\rho$$

$$\left.\begin{array}{ll}
-3 & \sin 2\tau \\
-\frac{21}{2}e' & \quad ,, \quad 2\tau - g' \\
+\frac{3}{2}e' & \quad ,, \quad 2\tau + g'
\end{array}\right| \delta v,$$

and also

$$\delta Q = \frac{\varrho}{\varrho'^3}(-3 \sin 2v - 2v')\,\delta\varrho$$

$$+ \frac{\varrho^2}{\varrho'^3}(-3 \cos 2v - 2v')\,\delta v$$

$$+ \varrho^2\left[\left(-\frac{3}{2}\sin 2v - 2v'\right)\delta\frac{1}{\varrho'^3} + 3\cos 2v - 2v')\,\frac{\delta v'}{\varrho'^3}\right],$$

where the terms containing $\delta\varrho$ and δv are (see Annex 2)

$$\left.\begin{array}{lll} -3 & \sin & 2\tau \\ -\frac{21}{2}e' & ,, & 2\tau - g' \\ +\frac{3}{2}e' & ,, & 2\tau + g' \end{array}\right|\delta\varrho$$

$$\left.\begin{array}{lll} -3 & \cos & 2\tau \\ -\frac{21}{2}e' & ,, & 2\tau - g' \\ +\frac{3}{2}e' & ,, & 2\tau + g' \end{array}\right|\delta v,$$

but the additional term $\frac{171}{4}m^2 e' \cos g'$ is ultimately added (see Annex 17) to the coefficient of δv.

Neglecting the terms in $\delta\varrho$, δv, we have (see Annex 4)

$$\begin{array}{lll} \delta P = \frac{3}{2}e' & t & \\ +\frac{3}{2} & t\cos & g' \\ -\frac{15}{2}e' & ,, & 2\tau \\ +\frac{21}{4} & ,, & 2\tau - g' \\ -\frac{3}{4} & ,, & 2\tau + g' \\ +\frac{9}{2}e' & ,, & 2g' \\ +\frac{51}{2}e' & ,, & 2\tau - 2g', \end{array}$$

$$\begin{array}{lll} \delta \dfrac{1}{\rho'^3} = & 3 e' & t \\ & + 3 & t \cos g' \\ & + \dfrac{9}{2} e' & \;,,\; 2g', \\ \dfrac{\delta v'}{\rho'^3} = & 2 & t \sin g' \\ & + \dfrac{11}{2} e' & \;,,\; 2g', \end{array}$$

which will be found useful.

II.

Proceeding now to the development of the solution, we have

$$\begin{aligned} \delta P = & \frac{1}{\rho'^3}\left(\frac{1}{2} + \frac{3}{2}\cos 2v - 2v'\right)\delta\rho \\ & + \frac{\rho}{\rho'^3}\left(\quad - \frac{3}{2}\sin 2v - 2v'\right)\delta v \\ & + \rho\left[\left(\frac{1}{2} + \frac{3}{2}\cos 2v - 2v'\right)\delta\frac{1}{\rho'^3} + \left(3 \sin 2v - 2v'\right)\frac{\delta v'}{\rho'^3}\right], \end{aligned}$$

where the terms containing $\delta\rho$ and δv are (see Annex 1)

$$\left.\begin{array}{lll} \dfrac{1}{2} & & \\ + \dfrac{3}{2} e' & \cos g' & \\ + \dfrac{3}{2} & \;,,\; & 2\tau \\ + \dfrac{21}{4} e' & \;,,\; & 2\tau - g' \\ - \dfrac{3}{4} e' & \;,,\; & 2\tau + g' \end{array}\right| \delta\rho$$

$$\left.\begin{array}{lll} - 3 & \sin & 2\tau \\ - \dfrac{21}{2} e' & \;,,\; & 2\tau - g' \\ + \dfrac{3}{2} e' & \;,,\; & 2\tau + g' \end{array}\right| \delta v,$$

and also

$$\delta Q = \frac{\rho}{\rho'^3}(-3 \sin 2v - 2v')\,\delta\rho$$

$$+ \frac{\rho^2}{\rho'^3}(-3 \cos 2v - 2v')\,\delta v$$

$$+ \rho^2\left[\left(-\frac{3}{2}\sin 2v - 2v'\right)\delta\frac{1}{\rho'^3} + 3\cos 2v - 2v')\,\frac{\delta v'}{\rho'^3}\right],$$

where the terms containing $\delta\rho$ and δv are (see Annex 2)

$$\left.\begin{array}{lll} -3 & \sin & 2\tau \\ -\frac{21}{2}e' & ,, & 2\tau - g' \\ +\frac{3}{2}e' & ,, & 2\tau + g' \end{array}\right|\delta\rho$$

$$\left.\begin{array}{lll} -3 & \cos & 2\tau \\ -\frac{21}{2}e' & ,, & 2\tau - g' \\ +\frac{3}{2}e' & ,, & 2\tau + g' \end{array}\right|\delta v,$$

but the additional term $\frac{171}{4} m^2 e' \cos g'$ is ultimately added (see Annex 17) to the coefficient of δv.

Neglecting the terms in $\delta\rho$, δv, we have (see Annex 4)

$$\begin{array}{rll} \delta P = \frac{3}{2}e' & t & \\ +\frac{3}{2} & t \cos & g' \\ -\frac{15}{2}e' & ,, & 2\tau \\ +\frac{21}{4} & ,, & 2\tau - g' \\ -\frac{3}{4} & ,, & 2\tau + g' \\ +\frac{9}{2}e' & ,, & 2g' \\ +\frac{51}{2}e' & ,, & 2\tau - 2g', \end{array}$$

and similarly (see Annex 5),

$$\begin{aligned}\delta Q = &\ \frac{15}{2} e' \quad t \sin 2\tau \\ &- \frac{21}{4} \quad\ \ ,, \ 2\tau - g' \\ &+ \frac{3}{4} \quad\ \ ,, \ 2\tau + g' \\ &- \frac{51}{2} e' \quad ,, \ 2\tau - 2g'.\end{aligned}$$

But in the foregoing expression of δ P the terms belonging to the arguments g', $2g'$ give in $\delta\varrho$, terms which rise by integration in δv; and in forming the expressions for δ P, δ Q, it is proper to take account of these terms. Attending only to the terms in question, we have

$$\frac{d^2\delta\varrho}{dt^2} + n^2\delta\varrho = m^2n^2\delta P = \overbrace{\begin{aligned}&\frac{3}{2} m^2 \quad\ \ t\cos g' \\ +&\frac{9}{2} m^2 e' \quad ,, \ 2g'.\end{aligned}}^{n^2\times}$$

Now in general, if

$$\frac{d^2\delta\varrho}{dt^2} + n^2\delta\varrho = n^2 \quad t\cos n\alpha t,$$

then

$$\delta\varrho = \frac{2\alpha}{(1-\alpha^2)^2}\sin n\alpha t + \frac{1}{1-\alpha^2} \quad t\cos n\alpha t;$$

and hence the foregoing equation gives in $\delta\varrho$ the terms

$$\begin{aligned}&3m^3 \quad \sin g' &&+ \frac{3}{2} \quad\ \ t\cos g' \\ +\ &18m^3e' \ ,, \ 2g' &&+ \frac{9}{2} m^2 e' \ ,, \ 2g';\end{aligned}$$

or, neglecting the terms which contain m^3, the terms of $\delta\varrho$ are

$$\begin{aligned}&\frac{3}{2} m^2 \quad\ \ t\cos g' \\ +&\frac{9}{2} m^2 e' \quad ,, \ 2g'.\end{aligned}$$

Substituting these terms in

$$\frac{d\,\delta v}{d\,t} = -2\,n\,\delta\varrho,$$

we have

$$\frac{d\,\delta v}{d\,t} = \overbrace{\begin{array}{ll} -3\,m^2 & t\cos g' \\ -9\,m^2 e' & \;\;,,\;\; 2\,g'; \end{array}}^{n\,\times}$$

and since, in general,

$$\int t\cos n\alpha t\,dt = \frac{1}{n^2\alpha^2}\cos n\alpha t + \frac{1}{n\alpha}\,t\sin n\alpha t,$$

we obtain in δv the terms

$$\overbrace{\begin{array}{ll} -3 & \cos g' \\ -\frac{9}{4}e' & ,,\; 2\,g' \end{array}}^{n^{-1}\,\times} + \overbrace{\begin{array}{ll} -3\,m & t\sin g' \\ -\frac{9}{2}\,m\,e' & ,,\; 2\,g', \end{array}}$$

or for the present purpose the terms

$$\overbrace{\begin{array}{ll} -3 & \cos g' \\ -\frac{9}{4}e' & ,,\; 2\,g'; \end{array}}^{n^{-1}\,\times}$$

and these give in δP the additional terms (see Annex 6)

$$\overbrace{\begin{array}{ll} \frac{27}{2} & \sin 2\,\tau \\ +\,\frac{9}{2} & ,,\; 2\,\tau - g' \\ +\,\frac{9}{2} & ,,\; 2\,\tau + g' \\ +\,\frac{153}{8}e' & ,,\; 2\,\tau - 2\,g' \\ +\,\frac{9}{8}\,e' & ,,\; 2\,\tau + 2\,g', \end{array}}^{n^{-1}\,\times}$$

and in δQ the additional terms (see Annex 7)

$$\overbrace{\begin{array}{lll} & \frac{27}{2} & \cos 2\tau \\ + & \frac{9}{2} & \;,,\; 2\tau - g' \\ + & \frac{9}{2} & \;,,\; 2\tau + g' \\ + & \frac{153}{8}e' & \;,,\; 2\tau - 2g' \\ + & \frac{9}{8}\,e' & \;,,\; 2\tau + 2g'. \end{array}}^{n^{-1}\times}$$

Combining the foregoing results, we have,

$$\begin{array}{rlll} \delta P = & \frac{3}{2}e' & t & + \\ + & \frac{3}{2} & t\cos g' & \\ - & \frac{15}{2}e' & \;,,\; 2\tau & \\ + & \frac{21}{4} & \;,,\; 2\tau - g' & \\ - & \frac{3}{4} & \;,,\; 2\tau + g' & \\ + & \frac{9}{2}e' & \;,,\; 2g' & \\ + & \frac{51}{2}e' & \;,,\; 2\tau - 2g' & \\ & 0 & \;,,\; 2\tau + 2g' & \end{array} \overbrace{\begin{array}{lll} & 0 & \sin g' \\ + & \frac{27}{2}e' & \;,,\; 2\tau \\ + & \frac{9}{2} & \;,,\; 2\tau - g' \\ + & \frac{9}{2} & \;,,\; 2\tau + g' \\ & 0 & \;,,\; 2g' \\ + & \frac{153}{8}e' & \;,,\; 2\tau - 2g' \\ + & \frac{9}{8}\,e' & \;,,\; 2\tau + 2g', \end{array}}^{n^{-1}\times}$$

and

$$\begin{array}{rlll} \delta Q = & 0 & t\sin g' & + \\ + & \frac{15}{2}e' & \;,,\; 2\tau & + \\ - & \frac{21}{4} & \;,,\; 2\tau - g' & + \end{array} \overbrace{\begin{array}{lll} 0 & \cos g' \\ \frac{27}{2}e' & \;,,\; 2\tau \\ \frac{9}{2} & \;,,\; 2\tau - g' \end{array}}^{n^{-1}\times}$$

$$
\begin{array}{llll}
 & & \multicolumn{2}{c}{\overbrace{\qquad\qquad}^{n^{-1}\times}} \\
+\frac{3}{4} & t\sin 2\tau+g' & +\frac{9}{2} & \cos 2\tau+g' \\
0 & \;,,\; 2g' & 0 & \;,,\; 2g' \\
-\frac{51}{2}e' & \;,,\; 2\tau-2g' & +\frac{153}{8}e' & \;,,\; 2\tau-2g' \\
0 & \;,,\; 2\tau+2g' & +\frac{9}{8}e' & \;,,\; 2\tau+2g';
\end{array}
$$

whence also (see Annex 8)

$$
n\int\delta Q\,dt =
\begin{array}{llll}
 & & \multicolumn{2}{c}{\overbrace{\qquad\qquad}^{n^{-1}\times}} \\
0 & t\cos g' & +\;0 & \sin g' \\
-\frac{15}{4}e' & \;,,\; 2\tau & +\frac{69}{8}e' & \;,,\; 2\tau \\
+\frac{21}{8} & \;,,\; 2\tau-g' & +\frac{15}{16} & \;,,\; 2\tau-g' \\
-\frac{3}{8} & \;,,\; 2\tau+g' & +\frac{39}{16} & \;,,\; 2\tau+g' \\
0 & \;,,\; 2g' & 0 & \;,,\; 2g' \\
+\frac{51}{4}e' & \;,,\; 2\tau-2g' & +\frac{51}{16}e' & \;,,\; 2\tau-2g' \\
0 & \;,,\; 2\tau+2g' & +\frac{9}{16}e' & \;,,\; 2\tau+2g'.
\end{array}
$$

The equation for $\delta\varrho$ may be written,

$$\frac{d^2\delta\varrho}{dt^2}+n^2\delta\varrho = m^2n^2\left(\delta P + 2n\int\delta Q\,dt\right),$$

and we have, (see Annex 9)

$$
\delta P + 2n\int\delta Q\,dt =
\begin{array}{llll}
\frac{3}{2}e'\;t & & + & \overbrace{\qquad\qquad}^{n^{-1}\times} \\
+\frac{3}{2} & t\cos g' & 0 & \sin g' \\
-15e' & \;,,\; 2\tau & +\frac{123}{4}e' & \;,,\; 2\tau \\
+\frac{21}{2} & \;,,\; 2\tau-g' & +\frac{51}{8} & \;,,\; 2\tau-g'
\end{array}
$$

$$\begin{array}{llll} & & & \overbrace{\qquad\qquad}^{n^{-1}\times} \\ -\frac{3}{2} & t\cos 2\tau+g' & +\frac{75}{8} & \sin 2\tau+g' \\ +\frac{9}{2}e' & ,,\ 2g' & 0 & ,,\ 2g' \\ +51e' & ,,\ 2\tau-2g' & +\frac{51}{2}e' & ,,\ 2\tau-2g' \\ 0 & ,,\ 2\tau+2g' & +\frac{9}{4}e' & ,,\ 2\tau+2g'. \end{array}$$

Hence observing that a term $n^2\, t\cos n\alpha t$ in $\frac{d^2\delta\varrho}{\delta t^2}+n^2\delta\varrho$, gives in $\delta\varrho$ the terms

$$\frac{1}{1-\alpha^2}\, t\cos n\alpha t \qquad + \frac{2\alpha}{(1-\alpha^2)^2}\,\frac{1}{n}\sin n\alpha t,$$

and a term $n\sin n\alpha t$ in $\frac{d^2\delta\varrho}{dt^2}+n^2\delta\varrho$, gives in $\delta\varrho$ the term

$$\frac{1}{1-\alpha^2}\;\frac{1}{n}\sin n\alpha t,$$

we have (see Annex 10, but restoring the factor f'),

$\delta\varrho = f'$ into as follows, viz.

$$\begin{array}{llll} \frac{3}{2}m^2e'\,t & & + & \overbrace{\qquad\qquad}^{n^{-1}\times} \\ +\frac{3}{2}m^2 & t\cos g' & 3m^3 & \sin g' \\ +5\,m^2e' & ,,\ 2\tau & -\frac{203}{12}m^2e' & ,,\ 2\tau \\ -\frac{7}{2}m^2 & ,,\ 2\tau-g' & +\frac{61}{24}m^2 & ,,\ 2\tau-g' \\ +\frac{1}{2}m^2 & ,,\ 2\tau+g' & -\frac{91}{24}m^2 & ,,\ 2\tau+g' \\ +\frac{9}{2}m^2e' & ,,\ 2g' & -18\,m^3e' & ,,\ 2g' \\ -17\,m^2e' & ,,\ 2\tau-2g' & +\frac{85}{6}m^2e' & ,,\ 2\tau-2g' \\ 0 & ,,\ 2\tau+2g' & -\frac{3}{4}m^2e' & ,,\ 2\tau+2g'. \end{array}$$

The first column, containing the term in t and the terms t cos arg., shows that the constant term of ϱ, and the terms involving the cosines of the same arguments, as obtained without attending to the variation of the solar excentricity, are correct as regards the first power of t, when for the constant excentricity e' we substitute $e' + f' t$. In fact, the above-mentioned expression (correct to e'^2) of $\frac{1}{\varrho}$ gives

$$\begin{array}{lll} \varrho = 1 - \frac{1}{6} m^2 + \frac{3}{4} m^2 e'^2 & & \\ \quad + \frac{3}{2} m^2 e'^2 & \cos g' \\ \quad - \quad m^2 + \frac{5}{2} m^2 e'^2 & ,, \; 2\tau \\ \quad - \frac{7}{2} m^2 e' & ,, \; 2\tau - g' \\ \quad + \frac{1}{2} m^2 e' & ,, \; 2\tau + g' \\ \quad + \frac{9}{4} m^2 e'^2 & ,, \; 2g' \\ \quad - \frac{17}{2} m^2 e'^2 & ,, \; 2\tau - 2g' \\ \quad \quad 0 & ,, \; 2\tau + 2g', \end{array}$$

and putting therein $e' + f' t$ in the place of e', we have the first column of the foregoing expression of $\delta \varrho$.

The second column, involving sin arg., contains the new periodic terms considered in Prof. Adams' Memoir of 1853, and the coefficients for the arguments g', 2τ, $2\tau - g'$, $2\tau + g'$, agree with his values; observing that his terms belong to $\delta \frac{1}{\varrho} = -\frac{\delta \varrho}{\varrho^2} = -\delta \varrho$, so that the signs are reversed; those for the remaining arguments $2g'$, $2\tau - 2g'$, $2\tau + 2g'$, are not given by him.

The equation for δv may be written,

$$\frac{d\delta v}{dt} = -2n\delta\varrho + m^2 n^2 \int \delta Q \, dt,$$

and we have (see Annex 11)

$$\begin{array}{llll} \dfrac{d\delta v}{dt} = \overbrace{- \; 3 m^2 e' \quad t}^{n \times} & & & \\ \quad - \; 3 \; m^2 \quad t \cos g' & & - \; 6 \; m^3 & \sin g \\ \quad + \frac{55}{4} m^2 e' \quad ,, \; 2\tau & & + \frac{1019}{24} m^2 e' & ,, \; 2\tau \end{array}$$

$$
n \times \overbrace{\begin{array}{lll}
+\frac{77}{8} & m^2 & t \cos 2\tau - g' \\
-\frac{11}{8} & m^2 & \;\;,, \;\; 2\tau + g' \\
-9 & m^2 e' & \;\;,, \;\; 2g' \\
+\frac{187}{8} & m^2 e' & \;\;,, \;\; 2\tau - 2g' \\
0 & & \;\;,, \;\; 2\tau + 2g'
\end{array}}
\qquad
\begin{array}{lll}
-\frac{199}{48} & m^2 & \sin 2\tau - g' \\
+\frac{481}{48} & m^2 & \;\;,, \;\; 2\tau + g' \\
-36 & m^3 e' & \;\;,, \;\; 2g' \\
-\frac{1207}{48} & m^2 e' & \;\;,, \;\; 2\tau - 2g' \\
+\frac{33}{16} & m^2 e' & \;\;,, \;\; 2\tau + 2g',
\end{array}
$$

whence, integrating by the formulæ

$$
\int t \cos n\alpha t \;\; dt = \frac{1}{n\alpha}\, t \sin n\alpha t + \frac{1}{n^2\alpha^2} \cos n\alpha t,
$$

$$
\int \sin n\alpha t \;\; dt = \qquad\qquad - \frac{1}{n\alpha} \cos n\alpha t,
$$

we have (see Annex 12, but restoring the factor f'),

$\delta v = f'$ into as follows, viz.

$$
\begin{array}{llll}
 & & -\frac{3}{2}\, m^2 n e' t^2 & \\
-3\, m & t \sin g' & + \overbrace{-3 + 6m^2}^{n^{-1} \times} & \cos g' \\
-\frac{55}{8}\, m^2 e' & \;\;,, \;\; 2\tau & -\frac{74}{3}\, m^2 e' & \;\;,, \;\; 2\tau \\
+\frac{77}{16}\, m^2 & \;\;,, \;\; 2\tau - g' & +\frac{215}{48}\, m^2 & \;\;,, \;\; 2\tau - g' \\
-\frac{11}{16}\, m^2 & \;\;,, \;\; 2\tau + g' & -\frac{257}{48}\, m^2 & \;\;,, \;\; 2\tau + g' \\
-\frac{9}{2}\, m e' & \;\;,, \;\; 2g' & \left(-\frac{9}{4} + 18m^2\right) e' & \;\;,, \;\; 2g' \\
+\frac{187}{8}\, m^2 e' & \;\;,, \;\; 2\tau - 2g' & +\frac{2239}{96}\, m^2 e' & \;\;,, \;\; 2\tau - 2g' \\
0 & \;\;,, \;\; 2\tau + 2g' & -\frac{33}{32}\, m^2 e' & \;\;,, \;\; 2\tau + 2g'.
\end{array}
$$

The first column, containing t sin arg., may be obtained from the before-mentioned expression (accurate to e'^2) of v, by substituting therein $e' + f' t$ in the place of e'.

The term $-\frac{3}{2} m^2 n e' f' t^2$; or, as it may be written, $-\frac{3}{2} m^2 \int n \left[\left(e' + f' t\right)^2 - e'^2\right] dt$, is the first term of the acceleration; the other terms of the second column are the new periodic terms in δv, considered by Prof. Adams; the coefficients for the arguments g', 2τ, $2\tau - g'$, $2\tau + g'$, agreeing with his values, but those for the remaining arguments $2g'$, $2\tau - 2g'$, $2\tau + 2g'$ not being given by him.

III.

Proceeding now to the calculation of the term in m^4 of the acceleration, we have,

$$\frac{d\delta v}{dt} = -\frac{2}{\rho}\frac{dv}{dt}\delta\rho + \frac{m^2 n^2}{\rho^2}\left(C + \int \delta Q\, dt\right),$$

where the non-periodic part of $\delta\rho$ is of the form,

$$\delta\rho = \left(\frac{3}{2} m^2 + \square\, m^4\right) e' f' t,$$

and it is in the first place necessary to find the value of the numerical coefficient $\square$, in fact to calculate the secular part of $\delta\rho$ as far as m^4. Reverting to the equation

$$\frac{d^2\delta\rho}{dt^2} + n^2\delta\rho =$$

$$\left(n^2 + \frac{2n^2}{\rho^3} - 3\left(\frac{dv}{dt}\right)^2\right)\delta\rho + m^2 n^2\left(\delta P + \frac{2}{\rho}\frac{dv}{dt}\left(C + \int \delta Q\, dt\right)\right),$$

and as before omitting in the process the factor f'.

The part $\left(n^2 + \frac{2n^2}{\rho^3} - 3\left(\frac{dv}{dt}\right)^2\right)\delta\rho$ contains (see Annex 13), a term

$$= \frac{381}{8} m^4 n^2 e' t.$$

The part of $m^2 n^2 \delta P$, which involves $\delta\rho$, contains (see Annex 14) a term

$$= -\frac{495}{32} m^4 n^2 e' t.$$

B

The part of $m^2 n^2 \delta P$, which depends on δv, contains a term

$$= -\frac{15}{4} m^4 n^2 e' t.$$

The part of $m^2 n^2 \delta P$, depending on $\delta \varrho'$ and $\delta v'$, is found (see Annex 18) to contain, besides the term $\frac{3}{2} m^2 n e' t$ in m^2 already obtained, a new term

$$= -\frac{647}{32} m^4 n^2 e' t.$$

And finally the part $m^2 n^2 \frac{2}{\varrho} \frac{dv}{dt} \left(C + \int \delta Q \, dt\right)$ is found (see Annex 19) to contain a term

$$\left(2 \cdot \frac{-1455}{32} + \frac{675}{32} = \right) - \frac{2235}{32} m^4 n^2 e' t.$$

where the component coefficient $-\frac{1455}{32}$, which arises from the new periodic terms of $\delta \varrho$ and δv is separately calculated (see Annex 21).

Hence $\frac{d^2 \delta \varrho}{dt^2} + n^2 \delta \varrho$ contains the term

$$\left(\square = \frac{381}{8} - \frac{495}{32} - \frac{15}{4} - \frac{647}{32} - \frac{2235}{32} = \right) - \frac{1973}{32} m^4 n^2 e' t,$$

and this gives in $\delta \varrho$ the term

$$-\frac{1973}{32} m^4 e' t,$$

so that, restoring the term in m^2, and the common factor f', the complete secular term of $\delta \varrho$ is

$$\delta \varrho = \left(\frac{3}{2} m^2 - \frac{1973}{32} m^4\right) e' f' t,$$

which, as will be shown, Art. IV., agrees with Prof. Adams' result.

Resuming now the equation,

$$\frac{d \delta v}{dt} = -\frac{2}{\varrho} \frac{dv}{dt} \delta \varrho + \frac{m^2 n^2}{\varrho^2} \left(C + \int \delta Q \, dt\right).$$

the part $-\frac{2}{\varrho}\frac{dv}{dt}\delta\varrho$ contains (see Annex 22) the term

$$\left(\frac{1973}{16}+\frac{275}{8}=\right)\frac{2523}{16}m^4 n e' t,$$

and the part $\frac{m^2 n^2}{\varrho^2}\left(C+\int\delta Q\,dt\right)$ contains (see Annex 23) the term

$$\left(\frac{45}{8}-\frac{1455}{32}=\right)-\frac{1275}{32}m^4 n e' t,$$

so that we have in $\frac{d\delta v}{dt}$ the term

$$\left(\frac{2523}{16}-\frac{1275}{32}=\right)\frac{3771}{32}m^4 n e' t,$$

giving in δv the term

$$\frac{3771}{64}m^4 n e' t^2,$$

or, restoring the term in m^2 and the common factor f', the complete secular term of δv is

$$\delta v=\left(-\frac{3}{2}m^2+\frac{3771}{64}m^4\right)n e' f' t^2,$$

which agrees with the value obtained by Prof. Adams. It is right to remark that the m of Prof. Adams is different from that of the present Memoir; we have in fact,

$$m\ (\text{Adams})=m\left\{1+\left(\frac{3}{2}m^2-\frac{3771}{64}m^4\right)2e'f't\right\}$$

in the notation of the present Memoir; but as f'^2 is throughout neglected, we may in the foregoing expression of the secular part of δv substitute the m of Prof. Adams. And then if the term be written in the form

$$\delta v=\left(-\frac{3}{2}m^2+\frac{3771}{64}m^4\right)\int\left[\left(e'+f't\right)^2-e'^2\right]n\,dt,$$

the two results are seen to agree together. But as regards the before-mentioned secular term,

$$\delta\epsilon = \left(\frac{3}{2}m^2 - \frac{1973}{32}m^4\right)e'f't,$$

the identification is less easy, and I shall consider it in the following article.

IV.

It will be convenient to write M, N, A, E′, in place of the m, n, a, e', of the foregoing part of the present Memoir, and to now use m, n, e', in the significations in which they are employed by Prof. Adams; E′ (the constant part of the solar excentricity) is his E′, and his e' is $E' + f't$. As to his symbols a, $a_{,}$, these, I think, ought to have been represented, and I shall here represent them by a, a$_{,}$.* And I take a such that $n^2a^3 =$ Sum of the masses of the Earth and Moon; or, taking this to be unity, we have $N^2A^3 = 1$, $n^2a^3 = 1$.

The formulæ of Prof. Adams' memoir, which it will be necessary to make use of, may be written

$$\begin{aligned}
\frac{\mathrm{a}}{r} = 1 - \frac{11}{8}m^2 - \frac{201}{16}m^4e'^2 & \\
-\frac{3}{2}m^2e' \qquad & \cos g' \\
+m^2 - \frac{5}{2}m^2e'^2 \quad & \;\;,,\;\; 2\tau \\
+\frac{7}{2}m^2e' \qquad & \;\;,,\;\; 2\tau - g' \\
-\frac{1}{2}m^2e' \qquad & \;\;,,\;\; 2\tau + g'
\end{aligned}$$

the sine terms being disregarded.

$$n = \mathrm{N}\left\{1 + \left(-\frac{3}{2}m^2 + \frac{3771}{64}m^4\right)2\,\mathrm{E}'f't\right\},$$

(whence also

$$m = \mathrm{M}\left\{1 + \left(\;\frac{3}{2}m^2 - \frac{3771}{64}m^4\right)2\,\mathrm{E}'f't\right\}$$

* Plana, in his Lunar Theory, uses the three letters a, a$_{,}$, a; his a and n being such that $n^2a^3 =$ Sum of the masses of the Earth and Moon. There is an obvious inconvenience in writing a, $a_{,}$, in the place of his a, a$_{,}$.

since $m = \frac{n'}{n}$, $\mathrm{M} = \frac{\mathrm{N}'}{\mathrm{N}}$).

$$\frac{1}{n} = \mathrm{a}_{,}^{\frac{3}{2}} \left\{ 1 + m^2 - \frac{197}{64} m^4 + \left(\quad \frac{3}{2} m^2 - \frac{3867}{64} m^4 \right) e'^2 \right\},$$

$$1 = \frac{\mathrm{a}}{\mathrm{a}_{,}} \left\{ 1 - \frac{1}{2} m^2 + \frac{13}{4} m^4 + \left(- \frac{3}{4} m^2 + \frac{3201}{64} m^4 \right) e'^2 \right\},$$

which formulæ, observing that $\frac{1}{\varrho + \delta\varrho} = \frac{\mathrm{A}}{r}$ lead to the value of $\delta\varrho$, and we should obtain for the secular part the foregoing expression, which will now be

$$\delta\varrho = \left(\frac{3}{2} \mathrm{M}^2 - \frac{1973}{32} \mathrm{M}^4 \right) \mathrm{E}' f' t.$$

We in fact have

$$a^{\frac{3}{2}} = \frac{1}{n} = \mathrm{a}_{,}^{\frac{3}{2}} \left\{ 1 + m^2 - \frac{197}{64} m^4 + \left(\frac{3}{2} m^2 - \frac{3867}{64} m^4 \right) e'^2 \right\},$$

And thence

$$\begin{aligned} a = \quad & \mathrm{a}_{,} \left\{ 1 + \frac{2}{3} m^2 - \frac{197}{96} m^4 + \left(m^2 - \frac{3867}{96} m^4 \right) e'^2 \right. \\ & \qquad \left. - \frac{1}{9} \left(\quad m^4 \qquad\qquad + 3\, m^4 e'^2 \right) \right\} \\ = \quad & \mathrm{a}_{,} \left\{ 1 + \frac{2}{3} m^2 - \frac{623}{288} m^4 + \left(m^2 - \frac{3899}{96} m^4 \right) e'^2 \right\}, \end{aligned}$$

but

$$1 = \frac{\mathrm{a}}{\mathrm{a}_{,}} \left\{ 1 - \frac{1}{2} m^2 + \frac{13}{4} m^4 + \left(- \frac{3}{4} m^2 + \frac{3201}{64} m^4 \right) e'^2 \right\};$$

and therefore

$$\begin{aligned} a = \mathrm{a} & \left\{ 1 + \frac{2}{3} m^2 - \frac{623}{288} m^4 + \left(m^2 - \frac{3899}{96} m^4 \right) e'^2 \right. \\ & \quad - \frac{1}{2} m^2 + \frac{13}{4} m^4 \qquad - \quad \frac{1}{2} \quad m^4 e'^2 \\ & \qquad - \frac{1}{3} \; m^4 + \left(- \frac{3}{4} m^2 + \frac{3201}{64} m^4 \right) e'^2 \\ & \qquad\qquad \left. - \; \frac{1}{2} \; m^4 e'^2 \right\} \\ = \mathrm{a} & \left\{ 1 + \frac{1}{6} m^2 + \frac{217}{288} m^4 + \left(\frac{1}{4} m^2 + \frac{1613}{192} m^4 \right) e'^2 \right\}; \end{aligned}$$

and hence, since for the non-periodic part

$$\frac{\mathrm{a}}{r} = 1 - \frac{11}{8} m^4 - \frac{201}{16} m^4 e'^2,$$

we find

$$\begin{aligned}\frac{a}{r} = 1 + \frac{1}{6} m^2 + \frac{217}{288} m^4 + \left(\frac{1}{4} m^2 + \frac{1613}{192} m^4\right) e'^2 \\ - \frac{11}{8} m^4 \qquad\qquad - \frac{201}{16} m^4 e'^2\end{aligned}$$

$$= 1 + \frac{1}{6} m^2 - \frac{179}{288} m^4 + \left(\frac{1}{4} m^2 - \frac{799}{192} m^4\right) e'^2$$

$$= 1 + \frac{1}{6} m^2 - \frac{179}{288} m^4 + \left(\frac{1}{4} m^2 - \frac{799}{192} m^4\right) \mathrm{E}'^2 + \left(\frac{1}{4} m^2 - \frac{799}{192} m^4\right) 2\,\mathrm{E}' f' t.$$

But

$$\frac{\mathrm{A}}{a} = \left(\frac{n}{\mathrm{N}}\right)^{\frac{2}{3}} = 1 + \left(- m^2 + \frac{3771}{96} m^4\right) 2\,\mathrm{E}' f' t;$$

and therefore

$$\begin{aligned}\frac{\mathrm{A}}{r} = \quad & 1 + \frac{1}{6} m^2 - \frac{179}{288} m^4 + \left(\frac{1}{4} m^2 - \frac{799}{192} m^4\right) \mathrm{E}'^2 + \left(\frac{1}{4} m^2 - \frac{799}{192} m^4\right) 2\,\mathrm{E}' f' t \\ & + \left(- m^2 + \frac{3771}{96} m^4\right) 2\,\mathrm{E}' f' t \\ & - \frac{1}{6} m^4 \,.\, 2\,\mathrm{E}' f' t\end{aligned}$$

$$= 1 + \frac{1}{6} m^4 - \frac{179}{288} m^4 + \left(\frac{1}{4} m^2 - \frac{799}{192} m^4\right) \mathrm{E}'^2 + \left(-\frac{3}{4} m^2 + \frac{2237}{64} m^4\right) 2\,\mathrm{E}' f' t.$$

But we have

$$m = \mathrm{M} \left\{ 1 + \left(\frac{3}{2} \mathrm{M}^2 - \frac{3771}{64} \mathrm{M}^4\right) 2\,\mathrm{E}' f' t \right\};$$

and thence in the foregoing expression

$$m^2 = \mathrm{M}^2 + 3\,\mathrm{M}^4 \,.\, 2\,\mathrm{E}' f' t.$$

$$m^4 = \mathrm{M}^4;$$

and therefore

$$\frac{A}{r}=1+\frac{1}{6}M^2-\frac{179}{288}M^4+\left(\frac{1}{4}M^2-\frac{799}{192}M^4\right)E'^2+\left(-\frac{3}{4}M^2+\frac{2237}{64}M^4\right)2E'f't$$
$$+\frac{1}{2}M^4 . 2E'f't$$
$$=1+\frac{1}{6}M^2-\frac{179}{288}M^4+\left(\frac{1}{4}M^2-\frac{799}{192}M^4\right)E'^2+\left(-\frac{3}{4}M^2+\frac{2269}{64}M^4\right)2E'f't;$$

and observing that in the periodic terms we may write A, in the place of a, and neglect the sine terms, we have

$$\begin{aligned}\frac{A}{r}=\frac{1}{\varrho+\delta\varrho}=1+\frac{1}{6}M^2-\frac{179}{288}M^4+\left(\frac{1}{4}M^2-\frac{799}{192}M^4\right)E'^2\\ +\left(-\frac{3}{4}M^2+\frac{2269}{64}M^4\right)2E'f't\end{aligned}$$
$$\begin{array}{ll} -\frac{3}{2}m^2e' & \cos g' \\ +m^2\left(1-\frac{5}{2}e'^2\right) & \quad ,, \ 2\tau \\ +\frac{7}{2}m^2e' & \quad ,, \ 2\tau-g' \\ -\frac{1}{2}m^2e' & \quad ,, \ 2\tau+g', \end{array}$$

say $\frac{1}{\varrho+\delta\varrho}=1+X$; and thence $\varrho+\delta\varrho=\frac{1}{1+X}=1-X+X^2$, the non-periodic part whereof is

$$\begin{aligned}1-\frac{1}{6}M^2+\frac{179}{128}M^4+\left(-\frac{1}{4}M^2+\frac{179}{192}M^4\right)E'^2+\left(\frac{3}{4}M^2-\frac{2269}{64}M^4\right)2E'f't\\ +\frac{1}{36}M^4 \qquad +\frac{1}{12}M^4E'^2 \qquad +\frac{1}{4}M^4 . 2E'f't\end{aligned}$$
$$\begin{array}{l} +\frac{1}{2}\frac{9}{4}\,m^4e'^2 \\ +\frac{1}{2}\quad m^4\left(1-5e'^2\right) \\ +\frac{1}{2}\frac{49}{4}\,m^4e'^2 \\ +\frac{1}{2}\frac{1}{4}\,m^4e'^2, \end{array}$$

where the terms in m^4 and $m^4 e'^2$ are

$$= \frac{1}{2} m^4 + \left(\frac{9}{8} - \frac{5}{2} + \frac{49}{8} + \frac{1}{8} =\right) \frac{39}{8} m^4 e'^2,$$

which are

$$= \frac{1}{2} \mathrm{M}^4 \qquad + \frac{39}{8} \mathrm{M}^4 \mathrm{E}'^2 \qquad + \frac{39}{8} \mathrm{M}.^4 \; 2\,\mathrm{E}'f'\,t.$$

so that the foregoing expression of the non-periodic part of $\varrho + \delta\varrho$ is

$$= 1 - \frac{1}{6} \mathrm{M}^2 + \left(\frac{179}{128} + \frac{1}{36} + \frac{1}{2} =\right) \frac{2219}{1152} \mathrm{M}^4$$

$$+ \left(-\frac{1}{4} \mathrm{M}^2 + \left(\frac{179}{192} + \frac{1}{12} + \frac{39}{8} =\right) \frac{1131}{192} \mathrm{M}^4\right) \mathrm{E}'^2$$

$$+ \left(\frac{3}{4} \mathrm{M}^2 + \left(-\frac{2269}{64} - \frac{1}{4} + \frac{39}{8} =\right) - \frac{1973}{64} \mathrm{M}^4\right) 2\,\mathrm{E}'f'\,t;$$

or the secular term of $\delta\varrho$ is

$$= \left(\frac{3}{4} \mathrm{M}^2 - \frac{1973}{64} \mathrm{M}^4\right) 2\,\mathrm{E}'f'\,t,$$

which is the required formula.

V.

It is interesting to see how the coefficient $\frac{3771}{64}$ is made up. In Prof. Adams' Memoir we have

$$\frac{3771}{64} =$$

$$= -\frac{3}{2} - \frac{3}{4} \qquad \left(= -\frac{9}{4}\right)$$

$$+ \frac{15}{4} + \frac{135}{64} - \frac{117}{8} + \frac{495}{128} - \frac{285}{16} - \frac{147}{16} - \frac{3}{16} - \frac{1323}{256} - \frac{27}{256}$$

$$\left(= -\frac{2391}{64}\right)$$

$$+ \frac{9}{2} - \frac{27}{4} - \frac{45}{2} - \frac{45}{2} - \frac{15}{2} - \frac{495}{32} + \frac{285}{4} - \frac{147}{4} - \frac{3}{4} + \frac{441}{8} + \frac{441}{8} + \frac{9}{8} + \frac{9}{8}$$

$$\left(= + \frac{3153}{32}\right),$$

where it may be remarked that the terms

$$\frac{495}{128}-\frac{285}{16}=\left(-\frac{1785}{128}\right)$$

and

$$-\frac{495}{32}+\frac{285}{4}=\left(+4\cdot\frac{1785}{128}\right)$$

make together $3\cdot\frac{1785}{128}=\frac{5355}{128}$, and that it is in fact by the addition of these terms that Plana's coefficient $\frac{2187}{128}$ is changed into $\frac{3771}{64}$.

But in the present Memoir the coefficient $\frac{3771}{64}$ is obtained by means of an entirely different set of component numbers, viz. we have

$$\frac{3771}{64}=-\frac{381}{8}+\frac{495}{32}+\frac{15}{4}+\frac{647}{32}+\frac{1455}{16}-\frac{675}{32}+\frac{275}{16}+\frac{45}{16}-\frac{1455}{64}.$$

I had imagined, from the way in which the numbers $\frac{1455}{16}$ $-\frac{1455}{64}$ presented themselves, that, if they were omitted, Plana's value $\frac{2187}{128}$ would have been obtained; but the result shows that this is not so.

As just deduced from the formula of Prof. Adams, the number $\frac{1973}{64}$ is obtained as follows, viz.

$$\frac{1973}{64}=$$

$$\left(-\frac{3771}{96}-1\right)-\frac{1}{3}-\frac{1}{2}+\left(\frac{3153}{64}+\frac{3}{4}\right)-\frac{1}{2}-\frac{201}{16}+\frac{3771}{96}-\frac{1}{6}-\frac{1}{2}+\frac{1}{4}-\frac{39}{8}$$

$$=-1-\frac{1}{3}-\frac{1}{2}+\frac{3}{4}-\frac{1}{2}-\frac{1}{6}-\frac{1}{2}+\frac{1}{4} \qquad (=-1)$$

$$+\frac{3153}{64}-\frac{201}{16}-\frac{39}{8},$$

where *ut suprà*

$$\frac{3153}{64}=$$

$$\frac{1}{2}\left\{\frac{9}{2}-\frac{27}{4}-\frac{45}{2}-\frac{45}{2}-\frac{15}{2}-\frac{495}{32}+\frac{285}{4}-\frac{147}{4}-\frac{3}{4}+\frac{441}{8}+\frac{441}{8}+\frac{9}{8}+\frac{9}{8}\right\},$$

$-\frac{201}{16}$ is a number occurring in his Memoir, and which is in effect obtained irrespectively of the new periodic terms, and $-\frac{39}{8}$ is a number obtained as above, irrespectively of the new periodic terms. According to the method of the present Memoir, the number $\frac{1973}{64}$ was obtained in the form

$$\frac{1973}{64} = -\frac{1}{2}\left(\frac{381}{8} - \frac{495}{32} - \frac{15}{4} - \frac{647}{32} - \frac{1455}{16} + \frac{675}{32}\right).$$

VI.

If the investigation were pursued further, a question would arise as to the proper form to be given to the arguments; for in these, $nt + \epsilon$ seems to stand in the place of v, the value whereof is

$$v = nt + \epsilon - \left(\frac{3}{2}m^2 - \frac{3771}{64}m^4\right) n e' f' t^2,$$

say $v = nt + \epsilon + k n e' f' t^2$, and it might be considered that in the arguments $nt + \epsilon$ should be changed into $nt + \epsilon + kne'f't^2$, or, what is the same thing, that τ should be changed into $\tau + kne'f't^2$, but that g' should remain unaltered (this assumes that there is not in the Sun's longitude any term corresponding to the acceleration). The arguments, instead of being of the simple form kt, would thus be of the form $kt + k_2 f' t^2$. But this would not only increase the difficulty of integration, but would be inconsistent with the general plan of the solution; and it would seem to be the proper course to imagine the cosine or sine of such an argument to be developed $\left(\begin{smallmatrix}\cos\\ \sin\end{smallmatrix} kt + k_2 f' t^2 = \begin{smallmatrix}\cos\\ \sin\end{smallmatrix} kt \mp k_2 f' t^2 \begin{smallmatrix}\sin\\ \cos\end{smallmatrix} kt\right)$ in such manner as to bring the secular part of the argument outside the cos or sin; this is, in fact, the form which the solution takes when the arguments are left throughout in their original form, for the terms of the form $f' t^2 \begin{smallmatrix}\cos\\ \sin\end{smallmatrix}$ arg. would present themselves in the subsequent approximations. But I shall not at present further examine the question.

Annexes containing the Details of the Calculation.

Annex 1.

Calculation of part of δP.

$$\delta P = \frac{1}{\varrho'^3}\left(\frac{1}{2}+\frac{3}{2}\cos 2v-2v'\right)\delta\varrho$$

$$+\frac{\varrho}{\varrho'^3}\left(-3\sin 2v-2v'\right)\delta v.$$

For $\cos 2v-2v'$, $\sin 2v-2v'$, see Annex 3.

$\frac{1}{2}+\frac{3}{2}\cos 2v-2v'=$	$\frac{1}{\varrho'^3}=$
$\frac{1}{2}$	1
$+\frac{3}{2}\cos 2\tau$	$+3e'\cos g'.$
$+3e'$,, $2\tau-g'$	
$-3e'$,, $2\tau+g'$	

Product is =

$$\frac{1}{2} \qquad +\frac{3}{2}e'\cos g'$$

$$+\frac{3}{2}\cos 2\tau \quad +\frac{9}{2}e'\left(\frac{1}{2}\cos 2\tau-g' \quad +\frac{1}{2}\cos 2\tau+g'\right)$$

$+3e'$,, $2\tau-g'$

$-3e'$,, $2\tau+g'$

$=\quad \frac{1}{2}$

$+\frac{3}{2}e'\cos g'$

$+\frac{3}{2}$,, 2τ

$\left(+3+\frac{9}{4}=\right)\quad +\frac{21}{4}e'$,, $2\tau-g'$

$\left(-3+\frac{9}{4}=\right)\quad -\frac{3}{4}e'$,, $2\tau+g'$,

which is the coefficient of $\delta\varrho$.

And

$-3 \sin 2v - 2v' =$	$\dfrac{1}{\rho'^3} =$
$-3 \quad \sin 2\tau$	1
$-6e' \;\;,, \;\; 2\tau - g'$	$+3e' \;\cos g'.$
$+6e' \;\;,, \;\; 2\tau + g'$	

Product is =

$$\begin{array}{lll} -3 & \sin 2\tau & \quad -9e'\left(\tfrac{1}{2}\sin 2\tau - g' + \tfrac{1}{2}\sin 2\tau + g'\right) \\ -6e' & ,, \; 2\tau - g' & \\ +6e' & ,, \; 2\tau + g' & \end{array}$$

$$\begin{array}{ll} = & -3 \quad \sin 2\tau \\ \left(-6-\tfrac{9}{2}=\right) & -\tfrac{21}{2}e' \;,, \; 2\tau - g' \\ \left(+6-\tfrac{9}{2}=\right) & +\tfrac{3}{2}e' \;,, \; 2\tau + g'; \end{array}$$

or, since $\rho = 1$, this is the coefficient of δv.

Annex 2.

Calculation of part of δ Q.

$$\delta Q = \quad \frac{\rho}{\rho'^3}(-3 \sin 2v - 2v')\,\delta\rho$$

$$+ \frac{\rho^2}{\rho'^3}(-3 \cos 2v - 2v')\,\delta v.$$

For $\cos 2v - 2v'$, $\sin 2v - 2v'$, see Annex 3.

$-3 \sin 2v - 2v' =$	$\dfrac{1}{\rho'^3} =$
$-3 \quad \sin 2\tau$	1
$-6e' \;\;,, \;\; 2\tau - g'$	$+3e' \;\cos g'.$
$+6e' \;\;,, \;\; 2\tau + g'$	

Product is =

$$\begin{array}{ll} -3 \quad \sin 2\tau & -9e'\left(\frac{1}{2}\sin 2\tau - g' + \frac{1}{2}\sin 2\tau + g'\right) \\ -6e' \quad ,, \quad 2\tau - g' & \\ -6e' \quad ,, \quad 2\tau + g' & \end{array}$$

$$\begin{array}{ll} = & -3 \quad \sin 2\tau \\ \left(-6-\frac{9}{2}=\right) & -\frac{21}{2}e' \quad ,, \quad 2\tau - g' \\ \left(+6-\frac{9}{2}=\right) & +\frac{3}{2}e' \quad ,, \quad 2\tau + g'; \end{array}$$

or, since $\varrho = 1$, this is the coefficient of $\delta\varrho$.

$$\begin{array}{l|l} -3\cos 2v - 2v' = & \frac{1}{\varrho'^3} = \\ -3 \quad \cos 2\tau & 1 \\ -6e' \quad ,, \quad 2\tau - g' & +3e' \cos g' \\ +6e' \quad ,, \quad 2\tau + g' & \end{array}$$

Product is =

$$\begin{array}{ll} -3 \quad \cos 2\tau & -9e'\left(\frac{1}{2}\cos 2\tau - g' + \frac{1}{2}\cos 2\tau + g'\right) \\ -6e' \quad ,, \quad 2\tau - g' & \\ +6e' \quad ,, \quad 2\tau + g' & \end{array}$$

$$\begin{array}{ll} = & -3 \quad \cos 2\tau \\ \left(-6-\frac{9}{2}=\right) & -\frac{21}{2}e' \quad ,, \quad 2\tau - g' \\ \left(+6-\frac{9}{2}=\right) & +\frac{3}{2}e' \quad ,, \quad 2\tau + g'; \end{array}$$

or, since $\varrho^2 = 1$, this is the coefficient of δv.

Annex 3.

Calculation of $\frac{\cos}{\sin}\, 2v - 2v'$.

$$v - v' = \tau - 2e' \sin g'$$

$$2v - 2v' = 2\tau - 4e' \sin g'$$

$$\begin{aligned}
\cos 2v - 2v' = &\quad \cos 2\tau \\
+ &\quad \sin 2\tau \,.\, 4e' \sin g' \\
= &\quad \cos 2\tau \\
&+ 2e' \;\;,,\;\; 2\tau - g' \\
&- 2e' \;\;,,\;\; 2\tau + g'
\end{aligned}$$

$$\begin{aligned}
\sin 2v - 2v' = &\quad \sin 2\tau \\
- &\quad \cos 2\tau \,.\, 4e' \sin g' \\
= &\quad \sin 2\tau \\
&+ 2e' \;\;,,\;\; 2\tau - g' \\
&- 2e' \;\;,,\;\; 2\tau + g'
\end{aligned}$$

The expressions are calculated (*post*, Annex 16) as far as m^2.

Annex 4.

Calculation of a part of δP.

$$\delta P = \varrho \left\{ \left(\frac{1}{2} + \frac{3}{2} \cos 2v - 2v' \right) \delta \frac{1}{\varrho'^3} + \left(3 \sin 2v - 2v' \right) \frac{\delta v'}{\varrho'^3} \right\}.$$

For $\cos 2v - 2v'$, $\sin 2v - 2v'$, see Annex 3.

$\frac{1}{2} + \frac{3}{2} \cos 2v - 2v' =$	$\delta \frac{1}{\varrho'^3} =$
$\frac{1}{2}$	$3e'\, t$
$+\frac{3}{2} \quad \cos 2\tau$	$+3 \quad t \cos g'$
$+3e' \;\;,,\;\; 2\tau - g'$	$+9e' \;\;,,\;\; 2g'$.
$-3e' \;\;,,\;\; 2\tau + g'$	

Product is =

$$
\begin{array}{llll}
 & \frac{3}{2}e' & t & \\
+ & \frac{9}{2}e' & t\cos 2\tau & \\
+ & \frac{3}{2} & \quad \text{,,}\ g' & \\
+ & \frac{9}{2} & \left(\frac{1}{2}t\cos 2\tau - g'\right. & \left. + \frac{1}{2}t\cos 2\tau + g'\right) \\
+ & 9e' & \left(\frac{1}{2}\ \text{,,}\ 2\tau - 2g'\right. & \left. + \frac{1}{2}\ \text{,,}\ 2\tau\right) \\
- & 9e' & \left(\frac{1}{2}\ \text{,,}\ 2\tau\right. & \left. + \frac{1}{2}\ \text{,,}\ 2\tau + 2g'\right) \\
+ & \frac{9}{2}e' & t\cos 2g' & \\
+ & \frac{27}{2}e' & \left(\frac{1}{2}t\cos 2\tau - 2g'\right. & \left. + \frac{1}{2}t\cos 2\tau + 2g'\right).
\end{array}
$$

which is =

$$
\begin{array}{rlll}
 & & \frac{3}{2}e' & t \\
 & + & \frac{3}{2} & t\cos g' \\
\left(\frac{9}{2}+\frac{9}{2}-\frac{9}{2}=\right) & + & \frac{9}{2}e' & \text{,,}\ 2\tau \\
 & + & \frac{9}{4} & \text{,,}\ 2\tau - g' \\
 & + & \frac{9}{4} & \text{,,}\ 2\tau + g' \\
 & + & \frac{9}{2}e' & \text{,,}\ 2g' \\
\left(\frac{9}{2}+\frac{27}{4}=\right) & + & \frac{45}{4}e' & \text{,,}\ 2\tau - 2g' \\
\left(-\frac{9}{2}+\frac{27}{4}=\right) & + & \frac{9}{4}e' & \text{,,}\ 2\tau + 2g'
\end{array}
$$

$$
\begin{array}{l|l}
3\sin 2v - 2v' = & \frac{\delta v'}{e'^3} = \\
\quad 3\ \sin 2\tau & \quad 2\ t\sin g' \\
\quad + 6e'\ \text{,,}\ 2\tau - g' & \quad + \frac{11}{2}e'\ \text{,,}\ 2g'; \\
\quad - 6e'\ \text{,,}\ 2\tau + g' &
\end{array}
$$

Product is =

$$
\begin{aligned}
& 6\ \left(\tfrac{1}{2}\ t\cos 2\tau - g' \;-\tfrac{1}{2}\ t\cos 2\tau + g'\ \right)\\
&+12\,e'\left(\tfrac{1}{2}\ \ ,,\ 2\tau - 2g' - \tfrac{1}{2}\ \ ,,\ 2\tau\ \right)\\
&-12\,e'\left(\tfrac{1}{2}\ \ ,,\ 2\tau \qquad\; - \tfrac{1}{2}\ \ ,,\ 2\tau + 2g'\right)\\
&+\tfrac{33}{2}\,e'\left(\tfrac{1}{2}\ \ ,,\ 2\tau - 2g' - \tfrac{1}{2}\ \ ,,\ 2\tau + 2g'\right),
\end{aligned}
$$

which is =

$$
\begin{array}{llll}
(-6-6=) & -12\,e' & t\cos & 2\tau \\
 & +3 & ,, & 2\tau - g' \\
 & -3 & ,, & 2\tau + g' \\
\left(6+\frac{33}{4}=\right) & +\frac{57}{4}\,e' & ,, & 2\tau - 2g' \\
\left(6-\frac{33}{4}=\right) & -\frac{9}{4}\,e' & ,, & 2\tau + 2g'.
\end{array}
$$

whence, adding the two products, and observing that $\epsilon^2 = 1$, the required terms are,

$$
\begin{array}{llll}
= & \frac{3}{2}\,e' & t & \\
 & +\frac{3}{2} & t\cos & g' \\
\left(\frac{9}{2}-12=\right) & -\frac{15}{2}\,e' & ,, & 2\tau \\
\left(\frac{9}{4}+3=\right) & +\frac{21}{4} & ,, & 2\tau - g' \\
\left(\frac{9}{4}-3=\right) & -\frac{3}{4} & ,, & 2\tau + g' \\
 & +\frac{9}{2}\,e' & ,, & 2g' \\
\left(\frac{45}{4}+\frac{57}{4}=\right) & +\frac{51}{2}\,e' & ,, & 2\tau - 2g' \\
\left(\frac{9}{4}-\frac{9}{4}=\right) & 0 & ,, & 2\tau + 2g'.
\end{array}
$$

Annex 5.

Calculation of a part of δQ, viz.

$$\delta Q = \varrho^2 \left[\left(-\frac{3}{2} \sin 2v - 2v' \right) \delta \frac{1}{\varrho'^3} + (3 \cos 2v - 2v') \frac{\delta v'}{\varrho'^3} \right],$$

$-\frac{3}{2} \sin 2v - 2v' =$	$\delta \frac{1}{\varrho'^3} =$
$-\frac{3}{2} \quad \sin 2\tau$	$3e' \quad t$
$-3e' \quad ,, \quad 2\tau - g'$	$+3 \quad t \cos g'$
$+3e' \quad ,, \quad 2\tau + g'$	$+9e' \quad ,, \quad 2g',$

Product is

$$
\begin{aligned}
& -\frac{9}{2} e' \quad t \sin 2\tau \\
& -\frac{9}{2} \left(\frac{1}{2} \quad t \sin 2\tau + g' \quad + \frac{1}{2} \quad t \sin 2\tau - g' \right) \\
& -9e' \left(\frac{1}{2} \quad ,, \quad 2\tau \quad + \frac{1}{2} \quad ,, \quad 2\tau - 2g' \right) \\
& +9e' \left(\frac{1}{2} \quad ,, \quad 2\tau + 2g' \quad + \frac{1}{2} \quad ,, \quad 2\tau \right) \\
& -\frac{27}{2} e' \left(\frac{1}{2} \quad ,, \quad 2\tau + 2g' \quad + \frac{1}{2} \quad ,, \quad 2\tau - 2g' \right),
\end{aligned}
$$

which is =

$$
\begin{aligned}
\left(-\frac{9}{2} - \frac{9}{2} + \frac{9}{2} = \right) \quad & -\frac{9}{2} e' \quad t \sin 2\tau \\
& -\frac{9}{4} \quad ,, \quad 2\tau - g' \\
& -\frac{9}{4} \quad ,, \quad 2\tau + g' \\
\left(-\frac{9}{2} - \frac{27}{4} = \right) \quad & -\frac{45}{4} e' \quad ,, \quad 2\tau - 2g' \\
\left(+\frac{9}{2} - \frac{27}{4} = \right) \quad & -\frac{9}{4} e' \quad ,, \quad 2\tau + 2g';
\end{aligned}
$$

and

$$\cos 2v - 2v' = \quad \begin{array}{ll} 3 & \cos 2\tau \\ +6e' & \;,,\; 2\tau - g' \\ -6e' & \;,,\; 2\tau + g' \end{array} \qquad\Bigg|\qquad \frac{\delta v'}{\varrho'^3} = \quad \begin{array}{ll} 2 & t \sin g' \\ +\frac{11}{2}e' & \;,,\; 2g', \end{array}$$

Product is

$$\begin{array}{l} 6\left(\frac{1}{2}\; t\sin 2\tau + 2g' \quad -\frac{1}{2}\; t\sin 2\tau - g'\right) \\ +12e'\left(\frac{1}{2} \quad ,,\; 2\tau \quad -\frac{1}{2} \quad ,,\; 2\tau - 2g'\right) \\ -12e'\left(\frac{1}{2} \quad ,,\; 2\tau + 2g' \quad -\frac{1}{2} \quad ,,\; 2\tau\right) \\ +\frac{33}{2}e'\left(\frac{1}{2} \quad ,,\; 2\tau + 2g' \quad -\frac{1}{2} \quad ,,\; 2\tau - 2g'\right); \end{array}$$

which is =

$$\begin{array}{rrl} (6+6=) & 12e' & t\sin 2\tau \\ & -3 & \;,,\; 2\tau - g' \\ & +3 & \;,,\; 2\tau + g' \\ \left(-6-\frac{33}{4}=\right) & -\frac{57}{4}e' & \;,,\; 2\tau - 2g' \\ \left(-6+\frac{33}{4}=\right) & +\frac{9}{4}e' & \;,,\; 2\tau + 2g'. \end{array}$$

Adding the two products together, and observing that $\varrho^2 = 1$, the required terms are

$$\begin{array}{rrl} \left(-\frac{9}{2}+12=\right) & \frac{15}{2}e' & t\sin 2\tau \\ \left(-\frac{9}{4}-3=\right) & -\frac{21}{4} & \;,,\; 2\tau - g' \\ \left(-\frac{9}{4}+3=\right) & +\frac{3}{4} & \;,,\; 2\tau + g' \\ \left(-\frac{45}{4}-\frac{57}{4}=\right) & -\frac{51}{2}e' & \;,,\; 2\tau - 2g' \\ \left(-\frac{9}{4}+\frac{9}{4}=\right) & 0 & \;,,\; 2\tau + 2g'. \end{array}$$

Annex 6.

Calculation of terms in δP, viz.

$$
\begin{array}{lll|}
-3 & & \sin 2\tau \\
-\frac{21}{2} & e' & \;,,\; 2\tau - g' \\
+\frac{3}{2} & e' & \;,,\; 2\tau + g'
\end{array}
\quad
\overbrace{
\begin{array}{lll}
-3 & & \cos g' \\
-\frac{9}{4} & e' & \;,,\; 2g';
\end{array}}^{n^{-1}\times}
$$

the product of which is

$$
\begin{array}{llll}
9 & \left(\frac{1}{2}\ \sin 2\tau + g'\right. & +\frac{1}{2}\ \sin 2\tau - g' & \left.\right) \\
+\frac{63}{2}e' & \left(\frac{1}{2}\ \;,,\; 2\tau\right. & +\frac{1}{2}\ \;,,\; 2\tau - 2g' & \left.\right) \\
-\frac{9}{2}e' & \left(\frac{1}{2}\ \;,,\; 2\tau + 2g'\right. & +\frac{1}{2}\ \;,,\; 2\tau & \left.\right) \\
+\frac{27}{4}e' & \left(\frac{1}{2}\ \;,,\; 2\tau + 2g'\right. & +\frac{1}{2}\ \;,,\; 2\tau - 2g' & \left.\right),
\end{array}
$$

which is =

$$
\begin{array}{lllll}
\left(\frac{63}{4} - \frac{9}{4} =\right) & & \overbrace{\frac{27}{2}} & e' & \sin 2\tau \\
 & + & \frac{9}{2} & & \;,,\; 2\tau - g' \\
 & + & \frac{9}{2} & & \;,,\; 2\tau + g' \\
\left(\frac{63}{4} + \frac{27}{8} =\right) & + & \frac{153}{8} & e' & \;,,\; 2\tau - 2g' \\
\left(-\frac{9}{4} + \frac{27}{8} =\right) & + & \frac{9}{8} & e' & \;,,\; 2\tau + 2g'.
\end{array}
$$

(The brace over the last block is labelled $n^{-1}\times$.)

Annex 7.

Calculation of terms in δQ, viz.

$$
\begin{array}{lll|lll}
 & & & & \overbrace{\qquad n^{-1}\times\qquad} & \\
-3 & \cos & 2\tau & -3 & \cos & g' \\
-\frac{21}{2}e' & ,, & 2\tau - g' & -\frac{9}{4}e' & ,, & 2g'; \\
+\frac{3}{2}e' & ,, & 2\tau + g' & & &
\end{array}
$$

the product of which is

$$
\begin{array}{llll}
9 & \left(\frac{1}{2}\cos 2\tau - g'\right. & + \frac{1}{2}\cos 2\tau + g' & \left.\right) \\
+\frac{63}{2}e' & \left(\frac{1}{2}\ ,,\ 2\tau - 2g'\right. & + \frac{1}{2}\ ,,\ 2\tau & \left.\right) \\
-\frac{9}{2}e' & \left(\frac{1}{2}\ ,,\ 2\tau\right. & + \frac{1}{2}\ ,,\ 2\tau + 2g' & \left.\right) \\
+\frac{27}{4}e' & \left(\frac{1}{2}\ ,,\ 2\tau - 2g'\right. & + \frac{1}{2}\ ,,\ 2\tau + 2g' & \left.\right),
\end{array}
$$

which is =

$$
\begin{array}{llll}
 & \overbrace{\qquad n^{-1}\times\qquad} & & \\
\left(\frac{63}{4} - \frac{9}{4} =\right) & \frac{27}{2}e' & \cos & 2\tau \\
 & +\frac{9}{2} & ,, & 2\tau - g' \\
 & +\frac{9}{2} & ,, & 2\tau + g' \\
\left(\frac{63}{4} + \frac{27}{8} =\right) & +\frac{155}{8}e' & ,, & 2\tau - 2g' \\
\left(-\frac{9}{4} + \frac{27}{8} =\right) & +\frac{9}{8}e' & ,, & 2\tau + 2g'.
\end{array}
$$

Annex 8.

Calculation of $n\int \delta Q\, dt$.

We have

$$n\int \sin n\alpha t\ dt = -\frac{1}{\alpha}\, t \cos n\alpha t + \frac{1}{n\alpha}\sin n\alpha t,$$

$$\int \cos n\alpha t\ dt = \qquad\qquad \frac{1}{n\alpha}\sin n\alpha t,$$

and in all the arguments α is taken $= 2$.

$$\begin{array}{rll|lll}
 & & & & \multicolumn{2}{l}{n^{-1}\times} \\
n\int \delta Q\, dt = -\frac{15}{4}e' & t\cos 2\tau & & \left(+\frac{15}{8}+\frac{27}{4}=\right) & +\frac{69}{8}e' & \sin 2\tau \\
+\frac{21}{8} & ,, & 2\tau - g' & \left(-\frac{21}{16}+\frac{9}{4}=\right) & +\frac{15}{16} & ,,\ 2\tau - g' \\
-\frac{3}{8} & ,, & 2\tau + g' & \left(+\frac{3}{16}+\frac{9}{4}=\right) & +\frac{39}{16} & ,,\ 2\tau + g' \\
+\frac{51}{4}e' & ,, & 2\tau - 2g' & \left(-\frac{51}{8}+\frac{153}{16}=\right) & +\frac{51}{16}e' & ,,\ 2\tau - 2g' \\
0 & ,, & 2\tau + 2g' & \left(\ 0+\frac{9}{16}=\right) & +\frac{9}{16} & ,,\ 2\tau + 2g'.
\end{array}$$

Annex 9.

Calculation of $\delta P + 2n\int \delta Q\, dt$; viz. this is

$$\begin{array}{rll|lll}
\frac{3}{2}e'\,t & & & & & \\
\frac{3}{2} & t\cos g' & & & \multicolumn{2}{l}{n^{-1}\times} \\
\left(-\frac{15}{2}-\frac{15}{2}=\right)-15e' & ,, & 2\tau & \left(+\frac{27}{2}+\frac{69}{4}=\right) & +\frac{123}{4}e' & \sin 2\tau \\
\left(+\frac{21}{4}+\frac{21}{4}=\right)+\frac{21}{2} & ,, & 2\tau - g' & \left(+\frac{9}{2}+\frac{15}{8}=\right) & +\frac{51}{8} & ,,\ 2\tau - g' \\
\left(-\frac{3}{4}-\frac{3}{4}=\right)-\frac{3}{2} & ,, & 2\tau + g' & \left(+\frac{9}{2}+\frac{39}{8}=\right) & +\frac{75}{8} & ,,\ 2\tau + g' \\
\left(+\frac{9}{2}+0=\right)+\frac{9}{2}e' & ,, & 2g' & \left(\ 0+0=\right) & 0 & ,,\ 2g' \\
\left(+\frac{51}{2}+\frac{51}{2}=\right)+51e' & ,, & 2\tau - 2g' & \left(+\frac{153}{8}+\frac{51}{8}=\right) & +\frac{51}{2}e' & ,,\ 2\tau - 2g' \\
\left(\ 0+0=\right)\ 0 & ,, & 2\tau + 2g' & \left(+\frac{9}{8}+\frac{9}{8}=\right) & +\frac{9}{4}e' & ,,\ 2\tau + 2g'.
\end{array}$$

Annex 10.

Calculation of $\delta\varrho$ from the equation

$$\frac{d^2\delta\varrho}{dt^2} + n^2 d\varrho = m^2n^2\left(\delta P + 2n\int \delta Q\,dt\right).$$

In $\frac{d^2\delta\varrho}{dt^2} + n^2\delta\varrho$, a term $n^2 t \cos n\alpha t$, gives in $\delta\varrho$,

$$\frac{1}{1-\alpha^2}\,t\cos n\alpha t + \frac{2\alpha}{(1-\alpha^2)^2}\,\frac{1}{n}\sin n\alpha t\,;$$

and a term $n\sin n\alpha t$, gives in $\delta\varrho$,

$$\frac{1}{1-\alpha^2}\,\frac{1}{n}\sin n\alpha t.$$

and $\alpha = 2$, and $\therefore \frac{1}{1-\alpha^2} = -\frac{1}{3}$, for all the args. except only $\alpha = m$ or $2m$, and $\therefore \frac{1}{1-\alpha^2} = 1$, for the args. g', $2g'$.

$$
\begin{array}{llll|l}
\delta\varrho = & \frac{3}{2}\,m^2e'\,t & & & \qquad\qquad\qquad \overbrace{\qquad\qquad\qquad}^{n^{-1}\,\times} \\
& +\frac{3}{2}\,m^2 & t\cos g' & & \left(+3 \qquad = \right) + 3\;m^3 \quad \sin g' \\
& +5\,m^2e' & ,, & 2\tau & \left(-\frac{20}{3}-\frac{41}{4} = \right) - \frac{203}{12}\,m^2e' \quad ,, \quad 2\tau \\
& -\frac{7}{2}\,m^2 & ,, & 2\tau - g' & \left(+\frac{14}{3}-\frac{17}{8} = \right) + \frac{61}{24}\,m^2 \quad ,, \quad 2\tau - g' \\
& +\frac{1}{2}\,m^2 & ,, & 2\tau + g' & \left(-\frac{2}{3}-\frac{25}{8} = \right) - \frac{91}{24}\,m^2 \quad ,, \quad 2\tau + g' \\
& +\frac{9}{2}\,m^2e' & ,, & 2g' & \left(+18 + 0 = \right) + 18\,m^3e' \quad ,, \quad 2g' \\
& -17\,m^2e' & ,, & 2\tau - 2g' & \left(+\frac{68}{3}+\frac{17}{2} = \right) + \frac{85}{6}\,m^2e' \quad ,, \quad 2\tau - 2g' \\
& 0 & ,, & 2\tau + 2g' & \left(\;0 - \frac{3}{4} = \right) - \frac{3}{4}\,m^2e' \quad ,, \quad 2\tau + 2g'.
\end{array}
$$

Annex 11.

Calculation of $\frac{d\,\delta v}{d\,t}$; viz. this is

$$= -2n\,\delta\varrho + m^2 n^2 \int \delta\,Q\,d\,t.$$

$$\frac{d\,\delta v}{d\,t} = \qquad \overbrace{\qquad n \times \qquad}$$

$\left(-3 \qquad =\right) - 3\ m^2 e'\ t$	
$\left(-3 \qquad =\right) - 3\ m^2\ \ t\cos g'$	$\left(-6 \qquad =\right) - 6\ m^3\ \sin g'$
$\left(-10-\frac{15}{4} =\right) - \frac{55}{4}\ m^2 e'$,, 2τ	$\left(+\frac{203}{6}+\frac{69}{8} =\right) + \frac{1019}{24}\ m^3 e'$,, 2τ
$\left(+7+\frac{21}{8} =\right) + \frac{77}{8}\ m^2$,, $2\tau - g'$	$\left(-\frac{61}{12}+\frac{15}{16} =\right) - \frac{199}{48}\ m^3$,, $2\tau - g'$
$\left(-1-\frac{3}{8} =\right) - \frac{11}{8}\ m^2$,, $2\tau + g'$	$\left(+\frac{91}{12}+\frac{39}{16} =\right) + \frac{481}{48}\ m^3$,, $2\tau + g'$
$\left(-9+0 =\right) - 9\ m^2 e'$,, $2g'$	$\left(-36+0 =\right) - 36\ m^3 e'$,, $2g'$
$\left(+34+\frac{51}{4} =\right) + \frac{187}{4} m^2 e'$,, $2\tau - 2g'$	$\left(-\frac{85}{3}+\frac{51}{16} =\right) - \frac{1207}{48} m^3 e'$,, $2\tau - 2g'$
$\left(\ 0+0\ \right)\ 0$,, $2\tau + 2g'$	$\left(+\frac{3}{2}+\frac{9}{16} =\right) + \frac{33}{16}\ m^3 e'$,, $2\tau + 2g'$.

Annex 12.

Calculation of δv from the foregoing value of $\frac{d\,\delta v}{d\,t}$.

We have

$$n \int \cos n\alpha t\ dt = \frac{1}{\alpha}\ t \sin n\alpha t + \frac{1}{n\alpha^2} \cos n\alpha t,$$

$$\int \sin n\alpha t\ dt = \qquad\qquad -\frac{1}{n\alpha} \cos n\alpha t;$$

$\alpha = 2$ for all the arguments, except only $\alpha = m$, $2\,m$, for the arguments g', $2\,g'$, respectively.

$\delta v =$	$\begin{array}{l} -\frac{3}{2} m^2 n e' \; t^2 \\ + \; \overbrace{n^{-1} \times} \end{array}$
$-3\, m \quad t \sin g'$	$\left(-\frac{3}{m^2} + 6 \; = \right) \; -3 \; + 6 m^2 \cos g'$
$-\frac{55}{8} m^2 e' \quad ,, \; 2\tau$	$\left(-\frac{55}{16} - \frac{1019}{48} = \right) \; - \frac{74}{3} \; m^2 e' \quad ,, \; 2\tau$
$+\frac{77}{16} m^2 \quad ,, \; 2\tau - g'$	$\left(+\frac{77}{32} + \frac{199}{96} = \right) \; + \frac{215}{48} m^2 \quad ,, \; 2\tau - g'$
$-\frac{11}{16} m^2 \quad ,, \; 2\tau + g'$	$\left(-\frac{11}{32} - \frac{481}{96} = \right) \; - \frac{257}{48} m^2 \quad ,, \; 2\tau + g'$
$-\frac{9}{2} \; m e' \quad ,, \; 2g'$	$\left(-\frac{9}{4m^2} + 18 \; = \right) \left(-\frac{9}{4} + 18 m^2\right) e' \; ,, \; 2g'$
$+\frac{187}{8} m^2 e' \quad ,, \; 2\tau - 2g'$	$\left(+\frac{187}{16} + \frac{1207}{96} = \right) \; + \frac{2329}{96} m^2 e' \quad ,, \; 2\tau - 2g'$
$0 \quad ,, \; 2\tau + 2g'$	$\left(\; 0 - \frac{33}{32} = \right) \; - \frac{33}{32} \; m^2 e' \quad ,, \; 2\tau + 2g'.$

The remaining Annexes relate to the determination of the non-periodic or secular terms of the order m^4, in $\delta\rho$ and δv respectively.

Annex 13.

Calculation of term of $\left(n^2 + \frac{2n^2}{\rho^3} - 3\left(\frac{dv}{dt}\right)^2\right) \delta\rho$.

We have

$n^2 + \frac{2n^2}{\rho^3} - 3\left(\frac{dv}{dt}\right)^2 =$	$\delta\rho =$
$\left(1 + 2 + m^2 - 3 \; = \right) \qquad \overbrace{n^2 \times} \; m^2$	$\frac{3}{2} m^2 e' \; t$
$\left(-9 + 18 = \right) + 9 \; m^2 e' \cos g'$	$+ \frac{3}{2} m^2 \quad t \cos g'$
$\left(+6 - \frac{33}{2} = \right) - \frac{21}{2} \; m^2 \quad ,, \; 2\tau$	$+ 5 \, m^2 e' \quad ,, \; 2\tau$
$\left(+21 - \frac{231}{4} = \right) - \frac{147}{4} m^2 e' \quad ,, \; 2\tau - g'$	$- \frac{7}{2} m^2 \quad ,, \; 2\tau - g'$
$\left(-3 + \frac{33}{4} = \right) + \frac{21}{4} \; m^2 e' \quad ,, \; 2\tau + g'$	$+ \frac{1}{2} m^2 \quad ,, \; 2\tau + g'$
	$+$ &c.

where, in the second factor, the arguments not occurring in the first factor are omitted, as not giving rise to any non-periodic

term; and so in other similar cases. Hence term of product is

$$
\begin{array}{rlll}
m^4 n^2 e' t & & 1 \,.\, & \frac{3}{2} \\[6pt]
& +\frac{1}{2}\,. & 9 \,.\, & \frac{3}{2} \\[6pt]
& +\frac{1}{2}\,. & -\frac{21}{2}\,. & 5 \\[6pt]
& +\frac{1}{2}\,. & -\frac{147}{4}\,. & -\frac{7}{2} \\[6pt]
& +\frac{1}{2}\,. & \frac{21}{4}\,. & \frac{1}{2}
\end{array}
$$

$$= \left(\frac{3}{2} + \frac{27}{4} - \frac{105}{4} + \frac{1029}{16} + \frac{21}{16} =\right) + \frac{381}{8}\, m^4 n^2 e' t.$$

Annex 14.

Calculation of term of $m^2 n^2 \delta P$.

$m^2 n^2 \delta P$, the part involving δv is

$$
\begin{array}{l|l}
 & \delta v = \\
\underbrace{m^2 n^2 \times}_{} & -3\,.\,m \quad t \sin g' \\[6pt]
-3 \quad \sin 2\tau & -\frac{55}{8} m^2 e' \quad ,, \quad 2\tau \\[6pt]
-\frac{21}{2} e' \quad ,, \quad 2\tau - g' & +\frac{77}{16} m^2 \quad ,, \quad 2\tau - g' \\[6pt]
+\frac{3}{2} e' \quad ,, \quad 2\tau + g' & -\frac{11}{16} m^2 \quad ,, \quad 2\tau + g' \\[6pt]
 & + \&c.
\end{array}
$$

and term of the product is

$$
\begin{array}{rlll}
m^4 n^2 e' t & \frac{1}{2}\,. & -3\,. & -\frac{55}{8} \\[6pt]
& +\frac{1}{2} & -\frac{21}{2}\,. & \frac{77}{16} \\[6pt]
& +\frac{1}{2}\,. & \frac{3}{2}\,. & -\frac{11}{16}
\end{array}
$$

$$= \left(\frac{165}{16} - \frac{1617}{64} - \frac{33}{64} =\right) - \frac{495}{32}\, m^4 n^2 e' t.$$

Annex 15.

Calculation of term of $m^2 n^2 \delta P$.

$m^2 n^2 \delta P$, the term involving $\delta \varrho$ is

$\overbrace{m^2 n^2 \times}$	$\delta \varrho =$
$\frac{1}{2}$	$\frac{3}{2} m^2 e' \; t$
$+ \frac{3}{2} \; e' \cos g'$	$+ \frac{3}{2} m^2 \quad t \cos g'$
$+ \frac{3}{2} \quad$,, 2τ	$+ 5 \, m^2 e' \quad$,, 2τ
$+ \frac{21}{4} \; e' \quad$,, $2\tau - g'$	$- \frac{7}{2} m^2 \quad$,, $2\tau - g'$
$- \frac{3}{4} \; e' \quad$,, $2\tau + g'$	$+ \frac{1}{2} m^2 \quad$,, $2\tau + g'$
	$+$ &c.

and term of the product is

$$m^4 n^2 e' t \qquad \frac{1}{2} \cdot \frac{3}{2}$$

$$+ \frac{1}{2} \cdot \frac{3}{2} \cdot \frac{3}{2}$$

$$+ \frac{1}{2} \cdot \frac{3}{2} \cdot 5$$

$$+ \frac{1}{2} \cdot \frac{21}{4} \cdot -\frac{7}{2}$$

$$+ \frac{1}{2} \cdot -\frac{3}{4} \cdot \frac{1}{2}$$

$$= \left(\frac{3}{4} + \frac{9}{8} + \frac{15}{4} - \frac{147}{16} - \frac{3}{16} = \right) - \frac{15}{4} m^4 n^2 e' t \, .$$

Annex 16.

Calculation of $\genfrac{}{}{0pt}{}{\cos}{\sin}\, 2v - 2v'$, as far as m^2.

$$\cos 2v - 2v' = \cos 2\tau + X = \cos 2\tau - X \sin 2\tau - \frac{1}{2} X^2 \cos 2\tau,$$

$$\sin 2v - 2v' = \sin 2\tau + X = \sin 2\tau + X \cos 2\tau - \frac{1}{2} X^2 \sin 2\tau,$$

where

$$\begin{aligned} X = & -\left(4 + 6m\right) e' && \sin g' \\ & + \frac{11}{4} m^2 && \;\;\text{,,}\;\; 2\tau \\ & + \frac{77}{8} m^2 e' && \;\;\text{,,}\;\; 2\tau - g' \\ & - \frac{11}{8} m^2 e' && \;\;\text{,,}\;\; 2\tau + g', \end{aligned}$$

and thence

$$\begin{aligned} X \sin 2\tau = & -\left(4 + 6m\right) e' && \left(\frac{1}{2} \cos 2\tau - g' \quad - \frac{1}{2} \cos 2\tau + g'\right) \\ & + \frac{11}{4} m^2 && \left(\frac{1}{2} \qquad\qquad\quad - \frac{1}{2} \;\text{,,}\; 4\tau \qquad\right) \\ & + \frac{77}{8} m^2 e' && \left(\frac{1}{2} \cos g' \qquad - \frac{1}{2} \;\text{,,}\; 4\tau - g'\right) \\ & - \frac{11}{8} m^2 e' && \left(\frac{1}{2} \;\text{,,}\; g' \qquad\;\; - \frac{1}{2} \;\text{,,}\; 4\tau + g'\right), \end{aligned}$$

which is =

$$
\begin{array}{lll}
 & \frac{11}{8}m^2 & \\
\left(\frac{77}{16}-\frac{11}{16}-\right) & +\frac{33}{8}m^2e' & \cos g' \\
 & -\left(2+3m\right)e' & \;\;,,\;\; 2\tau-g' \\
 & +\left(2+3m\right)e' & \;\;,,\;\; 2\tau+g' \\
 & -\frac{11}{8}m^2 & \;\;,,\;\; 4\tau \\
 & -\frac{77}{16}m^2e' & \;\;,,\;\; 4\tau-g' \\
 & +\frac{11}{16}m^2e' & \;\;,,\;\; 4\tau+g';
\end{array}
$$

$$
\begin{array}{llll}
X\cos 2\tau = & -\left(4+6m\right)e' & \left(\frac{1}{2}\sin 2\tau+g'\right. & \left.-\frac{1}{2}\sin 2\tau-g'\right) \\
 & +\frac{11}{4}m^2 & \left(\frac{1}{2}\;,,\;4\tau\right. & \left.\right) \\
 & +\frac{77}{8}m^2e' & \left(\frac{1}{2}\;,,\;4\tau-g'\right. & \left.-\frac{1}{2}\;,,\;g'\right) \\
 & -\frac{11}{8}m^2e' & \left(\frac{1}{2}\;,,\;4\tau+g'\right. & \left.-\frac{1}{2}\;,,\;g'\right),
\end{array}
$$

which is =

$$
\begin{array}{lll}
\left(-\frac{77}{16}-\frac{11}{16}-\right) & -\frac{11}{2}m^2e' & \sin g' \\
 & +\left(2+3m\right)e' & \;\;,,\;\; 2\tau-g' \\
 & -\left(2+3m\right)e' & \;\;,,\;\; 2\tau+g' \\
 & +\frac{11}{8}m^2 & \;\;,,\;\; 4\tau \\
 & +\frac{77}{16}m^2e' & \;\;,,\;\; 4\tau-g' \\
 & -\frac{11}{16}m^2e' & \;\;,,\;\; 4\tau+g';
\end{array}
$$

we have, moreover,

$$X^2 = -2\left(4+6m\right) e' \sin g' \,.\, \frac{11}{4} m^2 \sin 2\tau$$

$$= -22\, m^2 e' \left(\frac{1}{2}\cos 2\tau - g' \quad - \frac{1}{2}\cos 2\tau + g'\right)$$

$$= -11\, m^2 e' \quad \cos 2\tau - g'$$

$$+\, 11\, m^2 e' \quad ,, \quad 2\tau + g',$$

and thence

$$X^2 \cos 2\tau = -11\, m^2 e' \left(\frac{1}{2}\cos 4\tau - g' + \frac{1}{2}\cos g'\right)$$

$$+\, 11\, m^2 e' \left(\frac{1}{2} \;,,\; 4\tau + g' + \frac{1}{2} \;,,\; g'\right)$$

$$= \left(-\frac{11}{2} + \frac{11}{2} =\right) \quad 0 \qquad \cos g'$$

$$-\frac{11}{2} m^2 e' \qquad ,, \quad 4\tau - g'$$

$$+\frac{11}{2} m^2 e' \qquad ,, \quad 4\tau + g';$$

and

$$X^2 \sin 2\tau = -11\, m^2 e' \left(\frac{1}{2}\sin 4\tau - g' + \frac{1}{2}\sin g'\right)$$

$$-\, 11\, m^2 e' \left(\frac{1}{2} \;,,\; 4\tau + g' - \frac{1}{2} \;,,\; g'\right)$$

$$= \left(-\frac{11}{2} - \frac{11}{2} =\right) - 11\, m^2 e' \qquad \sin g'$$

$$-\frac{11}{2} m^2 e' \qquad ,, \quad 4\tau - g'$$

$$+\frac{11}{2} m^2 e' \qquad ,, \quad 4\tau + g';$$

and thence

$$
\begin{array}{lrll}
\cos 2v - 2v' = & & -\frac{11}{8}\,m^2 & \\
& & +\,1 & \cos 2\tau \\
& & -\frac{33}{8}\,m^2 e' & \;\;,,\;\; g' \\
& & +\left(2+3m\right)e' & \;\;,,\;\; 2\tau - g' \\
& & -\left(2+3m\right)e' & \;\;,,\;\; 2\tau + g' \\
& & +\frac{11}{8}\,m^2 & \;\;,,\;\; 4\tau \\
& \left(+\frac{77}{16}+\frac{11}{4}=\right) & +\frac{121}{16}\,m^2 e' & \;\;,,\;\; 4\tau - g' \\
& \left(-\frac{11}{16}-\frac{11}{4}=\right) & -\frac{55}{16}\,m^2 e' & \;\;,,\;\; 4\tau + g';
\end{array}
$$

and

$$
\begin{array}{lrll}
\sin 2v - 2v' = & & 1 & \sin 2\tau \\
& \left(-\frac{11}{2}+\frac{11}{2}=\right) & 0\;\; m^2 e' & \;\;,,\;\; g' \\
& & +\left(2+3m\right)e' & \;\;,,\;\; 2\tau - g' \\
& & -\left(2+3m\right)e' & \;\;,,\;\; 2\tau + g' \\
& & +\frac{11}{8}\,m^2 & \;\;,,\;\; 4\tau \\
& \left(\frac{77}{16}+\frac{11}{4}=\right) & +\frac{121}{16}\,m^2 e' & \;\;,,\;\; 4\tau - g' \\
& \left(-\frac{11}{16}-\frac{11}{4}=\right) & -\frac{55}{16}\,m^2 e' & \;\;,,\;\; 4\tau + g'.
\end{array}
$$

Annex 17.

Calculation of term in δQ.

The part of δQ containing δv is $\frac{\varrho^2}{\varrho'^3}\Big(-3\cos 2v - 2v'\Big)\,\delta v$; and it is necessary to find in $\frac{\varrho^2}{\varrho'^3}\Big(-3\cos 2v - 2v'\Big)$ the coefficient of $\cos g'$ as far as m^2; this is, in fact, required *post* Annex 21, for the calculation of $m^2 n^2\,(C + \int \delta Q\, dt)$.

$$
\begin{array}{lll|lll}
\varrho^2 = 1 - \frac{1}{3}m^2 & & & \frac{1}{\varrho'^3} = & 1 & \\
\quad + 3\,m^2 e' & \cos g' & & & + 3\,e' & \cos g' \\
\quad - 2\,m^2 & \;\;,, \;\; 2\tau & & & & \\
\quad - 7\,m^2 e' & \;\;,, \;\; 2\tau - g' & & & & \\
\quad + 1\,m^2 e' & \;\;,, \;\; 2\tau + g' & & & &
\end{array}
$$

and thence

$$
\begin{array}{rll|lll}
\frac{\varrho^2}{\varrho'^3} = & & & -3\cos 2v - 2v' = & & \\
1 - \frac{1}{3}m^2 & & & \frac{33}{8}m^2 & & \\
+\Big(3 + 2\,m^2\Big)e' & \cos g' & & + \frac{99}{8}m^2 e' & \cos g' & \\
- 2\,m^2 & \;\;,, \;\; 2\tau & & - 3 & \;\;,, \;\; 2\tau & \\
\Big(-7 - \frac{1}{2}.2.3 =\Big) - 10\,m^2 e' & \;\;,, \;\; 2\tau - g' & & -\Big(6 + 9\,m\Big)e' & \;\;,, \;\; 2\tau - g' & \\
\Big(+1 - \frac{1}{2}.2.3 =\Big) - 2\,m^2 e' & \;\;,, \;\; 2\tau + g' & & +\Big(6 + 9\,m\Big)e' & \;\;,, \;\; 2\tau + g' & \\
& & & \&c. & &
\end{array}
$$

where, in the second column, the omitted terms have arguments containing $4\,\tau$, and, consequently, do not, by combination with the first column, give rise to any term with the argument g'. The term arg. g' arises from the combinations

$$
\begin{array}{llll}
\frac{33}{8} m^2 & . \, 3 e' & \cos g' & \\
+ \frac{99}{8} m^2 e' . \, 1 & & ,, \; g' & \\
- 3 & . - 10 \, m^2 e' & \left(\cos 2\tau \cos 2\tau - g' = \frac{1}{2} \cos 4\tau - g' + \frac{1}{2} \cos g' \right) & \\
- 3 & . - 2 \, m^2 e' & \left(,, \; 2\tau \; ,, \; 2\tau + g' = \frac{1}{2} \; ,, \; 4\tau + g' + \frac{1}{2} \; ,, \; g' \right) & \\
- 6 e' . & - 2 \, m^2 & \left(,, \; 2\tau \; ,, \; 2\tau - g' = \frac{1}{2} \; ,, \; 4\tau - g' + \frac{1}{2} \; ,, \; g' \right) & \\
+ 6 e' . & - 2 \, m^2 & \left(,, \; 2\tau \; ,, \; 2\tau + g' = \frac{1}{2} \; ,, \; 4\tau + g' + \frac{1}{2} \; ,, \; g' \right) &
\end{array}
$$

so that the required term is

$$\left(\frac{99}{8} + \frac{99}{8} + 15 + 3 + 6 - 6 = \right) + \frac{171}{4} m^2 e' \cos g'.$$

and annexing this to the terms found Annex 2, the part of δQ which contains δv is

$$
\left.
\begin{array}{lll}
\frac{171}{4} m^2 e' & \cos g' \\
- 3 & ,, \; 2\tau \\
- \frac{21}{2} e' & ,, \; 2\tau - g' \\
+ \frac{3}{2} e' & ,, \; 2\tau + g'
\end{array}
\right| \delta v.
$$

Annex 18.

Calculation of term of $m^2 n^2 \delta P$.

The part of δP involving $\delta v'$ and $\delta \varrho$ is

$$\delta P = \varrho \left[\left(\frac{1}{2} + \frac{3}{2} \cos 2v - 2v' \right) \delta \frac{1}{\varrho'^3} + \left(3 \sin 2v - 2v' \right) \frac{\delta v'}{\varrho'^3} \right];$$

$\rho =$	$\frac{1}{2} + \frac{3}{2}\cos 2v - 2v' =$	$\delta\,\frac{1}{\rho^3} =$
$1 - \frac{1}{6}m^2$	$\frac{1}{2} - \frac{33}{16}m^2$	$3e'\ t$
$+\frac{3}{2}m^2 e' \cos g'$	$-\frac{99}{16}m^2 e' \quad \cos g'$	$+3 \quad t\cos 2g'$
$-\ m^2 \quad \text{,,}\ 2\tau$	$+\frac{3}{2} \quad \text{,,}\ 2\tau$	$+9e' \quad \text{,,}\ 2g'$
$-\frac{7}{2}m^2 e' \quad \text{,,}\ 2\tau - g'$	$+\left(3+\frac{9}{2}m\right)e' \quad \text{,,}\ 2\tau - g'$	
$+\frac{1}{2}m^2 e' \quad \text{,,}\ 2\tau + g'$	$-\left(3+\frac{9}{2}m\right)e' \quad \text{,,}\ 2\tau + g'$	
	$+$ &c.	

where, in the second factor, the terms belonging to the arguments which contain 4τ (*i.e.* the arguments 4τ, $4\tau - g'$, $4\tau + g'$) are omitted. In fact, the terms in question would, in the product of the second and third factors, give rise to terms with arguments containing 4τ, and as there are no such terms in the first factor, there is no resulting secular term.

The product of the second and third factors is

$$
\begin{aligned}
& \left(\frac{3}{2} - \frac{99}{16}m^2\right)e' \quad t \\
& + \left(\frac{3}{2} - \frac{99}{16}m^2\right) \quad t\cos g' \\
& + \frac{9}{2}e' \quad \text{,,}\ 2\tau \\
& \quad -\frac{297}{16}m^2 e' \left(\frac{1}{2}t \qquad + \frac{1}{2}t\cos 2g' \right) \\
& \quad + \frac{9}{2} \quad \left(\frac{1}{2}t\cos 2\tau - g' \quad + \frac{1}{2} \ \text{,,}\ 2\tau + g'\right) \\
& + \left(9 + \frac{27}{2}m\right)e' \left(\frac{1}{2}t \ \text{,,}\ 2\tau - 2g' \quad + \frac{1}{2} \ \text{,,}\ 2\tau \right) \\
& - \left(9 + \frac{27}{2}m\right)e' \left(\frac{1}{2} \ \text{,,}\ 2\tau + 2g' \quad + \frac{1}{2} \ \text{,,}\ 2\tau \right) \\
& + \left(\frac{9}{2} - \frac{297}{16}m^2\right)e' \quad t\cos 2g' \\
& + \frac{27}{2}e' \quad \left(\frac{1}{2}t\cos 2\tau - 2g' \quad + \frac{1}{2}t\cos 2\tau + 2g'\right),
\end{aligned}
$$

and we may in this product omit the terms with arguments containing $2g'$, since the first factor does not contain any such term. The product then is

$$
\begin{array}{llll}
\left(-\frac{99}{16}-\frac{297}{32}=-\frac{495}{32}\right) & \left(\frac{3}{2}-\frac{495}{32}m^2\right)e' & & t \\
 & +\left(\frac{3}{2}-\frac{99}{16}m^2\right) & & t\cos g' \\
\left(\left(\frac{9}{2}+\frac{9}{2}-\frac{9}{2}\right)e'+\left(\frac{27}{4}-\frac{27}{4}\right)me'\right) & +\frac{9}{2}e' & ,, & 2\tau \\
 & +\frac{9}{4} & ,, & 2\tau-g' \\
 & +\frac{9}{4} & ,, & 2\tau+g',
\end{array}
$$

which is to be multiplied by the first factor, ϱ, and the whole by the factor $m^2 n^2$.

The term in the product is

$$
\begin{array}{lll}
m^2n^2e't & \left(\frac{3}{2}-\frac{495}{32}m^2\right) & \left(1-\frac{1}{6}m^2\right) \\
 & +\frac{1}{2}\cdot\frac{3}{2} & \cdot\ \frac{3}{2}m^2 \\
 & +\frac{1}{2}\cdot\frac{9}{2} & \cdot\ -m^2 \\
 & +\frac{1}{2}\cdot\frac{9}{4} & \cdot\ -\frac{7}{2}m^2 \\
 & +\frac{1}{2}\cdot\frac{9}{4} & \cdot\ \frac{1}{2}m^2,
\end{array}
$$

giving the term $\frac{3}{2}m^2n^2e't$, which was found above, Annex 9, and the new terms

$$\left(-\frac{495}{32}-\frac{1}{4}+\frac{9}{8}-\frac{9}{4}-\frac{63}{16}+\frac{9}{16}=\right)-\frac{647}{32}m^4n^2e't.$$

The term of the part containing $\delta v'$ is found to be $=0$; In fact, we have

$\rho =$	$3 \sin 2v - 2v' =$	$\dfrac{\delta v'}{\rho'^3} =$
$1 - \frac{1}{6} m^2$	$3 \quad \sin 2\tau$	$2 \quad t \sin g'$
$+ \frac{3}{2} m^2 e' \cos g'$	$+ \left(6 + 9m\right) e' \quad ,, \quad 2\tau - g'$	$+ \frac{11}{2} e' \quad ,, \quad 2g'$
$- m^2 \quad ,, \quad 2\tau$	$- \left(6 + 9m\right) e' \quad ,, \quad 2\tau + g'$	
$- \frac{7}{2} m^2 e' \quad ,, \quad 2\tau - g'$	&c.	
$+ \frac{1}{2} m^2 e' \quad ,, \quad 2\tau + g'$		

where in the second factor the terms with arguments containing 4τ are for the before-mentioned reason omitted.

The product of the second and third factors is

$$\begin{aligned}
&6 \left(\frac{1}{2} t \cos 2\tau - g' \quad - \frac{1}{2} t \cos 2\tau + g' \right) \\
&+ \left(12 + 18m\right) e' \left(\frac{1}{2} \quad ,, \quad 2\tau - 2g' - \frac{1}{2} \quad ,, \quad 2\tau \right) \\
&- \left(12 + 18m\right) e' \left(\frac{1}{2} \quad ,, \quad 2\tau \quad - \frac{1}{2} \quad ,, \quad 2\tau + 2g'\right) \\
&+ \frac{33}{2} e' \quad \left(\frac{1}{2} \quad ,, \quad 2\tau - 2g' - \frac{1}{2} \quad ,, \quad 2\tau + 2g'\right)
\end{aligned}$$

which, omitting the terms with arguments containing $2g'$, is

$$\begin{aligned}
- (6 + 9m + 6 + 9m) = - (12 + 18m)\, e' \quad & t \cos 2\tau \\
+ 3 \quad & ,, \quad 2\tau - g' \\
- 3 \quad & ,, \quad 2\tau + g'
\end{aligned}$$

which is to be multiplied by the first factor, ρ, and the whole by $m^2 n^2$. The term is

$$\begin{aligned}
m^4 n^2 e' t \quad & \frac{1}{2} \cdot - 12 \cdot - 1 \\
& + \frac{1}{2} \cdot \quad 3 \cdot - \frac{7}{2} \\
& + \frac{1}{2} \cdot - 3 \cdot \quad \frac{1}{2}
\end{aligned}$$

which is

$$\left(6 - \frac{21}{4} - \frac{3}{4} =\right) 0 \quad m^4 n^2 e' t.$$

Hence the entire term in question is the before-mentioned value

$$-\frac{647}{32}\, m^4 n^2 e' t.$$

Annex 19.

Calculation of term in $m^2 n^2 \dfrac{2}{\varrho} \dfrac{dv}{dt}\left(\mathrm{C} + \displaystyle\int \delta \mathrm{Q}\, dt\right)$.

We have

$$\frac{2}{\varrho}\frac{dv}{dt} =$$

$$\begin{array}{lll}
\overbrace{\phantom{2 + \frac{1}{3} m^2}}^{n\,\times} & & \\
2 + \frac{1}{3} m^2 & & \\
- 9\, m^2 e' & \cos & g' \\
+ \frac{15}{2} m^2 & \;\;,, & 2\tau \\
+ \frac{105}{4} m^2 e' & \;\;,, & 2\tau - g' \\
- \frac{15}{4} m^2 e' & \;\;,, & 2\tau + g'
\end{array}$$

See *post* Annex 20.

$$m^2 n^2 \left(\mathrm{C} + \int \delta \mathrm{Q}\, dt\right) =$$

$$\begin{array}{lll}
\overbrace{\phantom{-\frac{1455}{32} m^4 e' t}}^{n\,\times} & & \\
-\frac{1455}{32} m^4 e' t & & \\
0 & t \cos & g' \\
- \frac{15}{4} m^2 & \;\;,, & 2\tau \\
+ \frac{21}{8} m^2 & \;\;,, & 2\tau - g' \\
- \frac{3}{8} m^2 & \;\;,, & 2\tau + g'
\end{array}$$

For the term $-\dfrac{1455}{32} m^4 e' t$ see *post* Annex 21.

The term in the product therefore is

$$\begin{array}{lrcl}
m^4 n^2 e' t & & 2 & . -\frac{1455}{32} \\
& + \frac{1}{2}\,. & \frac{15}{2} & . -\frac{15}{4} \\
& + \frac{1}{2}\,. & \frac{105}{4} & . -\frac{21}{8} \\
& + \frac{1}{2}\,. & -\frac{15}{4} & . -\frac{3}{8}
\end{array}$$

which is

$$= \left(2\,.\,-\frac{1455}{32} - \frac{225}{16} + \frac{2205}{64} + \frac{45}{64}\right) m^4 n^2 e' t$$

$$= \left(2\,.\,-\frac{1455}{32} + \frac{675}{32} =\right) \quad -\frac{2235}{32}\, m^4 n^2 e' t.$$

Annex 20.

Calculation of $\frac{2}{\varrho}\frac{dv}{dt}$.

We have

$\frac{dv}{dt} =$	$\frac{2}{\varrho} =$
$n \times \overbrace{1}$	$2 + \frac{1}{3} m^2.$
$- 3\, m^2 e' \cos g'$	$- 3\, m^2 e' \cos g'$
$+ \frac{11}{4} m^2 e'$,, 2τ	$+ 2\, m^2$,, 2τ
$+ \frac{77}{8} m^2 e'$,, $2\tau - g'$	$+ 7\, m^2 e'$,, $2\tau - g'$
$- \frac{11}{8} m^2 e'$,, $2\tau + g'$	$- 1\, m^2 e'$,, $2\tau + g'$

so that the product is

$$n \times \overbrace{2 + \frac{1}{3} m^2}$$

$$\left(-\,6 - 3 =\right) \quad -\,9\; m^2 e' \cos g'$$

$$\left(+\frac{11}{2} + 1 =\right) \quad +\frac{15}{2}\, m^2 \quad ,,\; 2\tau$$

$$\left(+\frac{77}{4} + 7 =\right) \quad +\frac{105}{4}\, m^2 e' \quad ,,\; 2\tau - g'$$

$$\left(-\frac{11}{4} - 1 =\right) \quad -\frac{15}{8}\, m^2 e' \quad ,,\; 2\tau + g'.$$

Annex 21.

Calculation of a term in $m^2 n^2 (C + \int \delta Q\, dt)$.

The part $\frac{\varrho}{\varrho'^3}\left(-3 \sin 2\, v - 2\, v'\right) \delta\varrho$ of δQ gives

$\frac{\varrho}{\varrho'^3}\left(-3 \sin 2 v - 2 v'\right) =$			$\delta\varrho =$ $n^{-1} \times$		
			$3\ m^3$		$\sin g'$
-3		$\sin 2\tau$	$-\frac{203}{12}$	$m^2 e'$	,, 2τ
$-\frac{21}{2}$	e'	,, $2\tau - g$	$+\frac{61}{24}$	m^2	,, $2\tau - g'$
$+\frac{3}{2}$	e'	,, $2\tau + g'$	$-\frac{91}{24}$	m^2	,, $2\tau + g'$

and we have thence in $m^2 n^2 \delta Q$ the term

$$
\begin{array}{ll}
m^4 n e' & \frac{1}{2} \cdot -3 \cdot -\frac{203}{12} \\
& + \frac{1}{2} \cdot -\frac{21}{2} \cdot \frac{61}{24} \\
& + \frac{1}{2} \cdot \frac{3}{2} \cdot -\frac{91}{24};
\end{array}
$$

that is

$$\left(\frac{203}{8} - \frac{427}{32} - \frac{91}{32} = \right) + \frac{147}{16} m^4 n e'.$$

The part $\frac{\varrho^2}{\varrho'^3}\left(3 \cos 2\, v - 2\, v'\right) \delta v$ of δQ gives

$\frac{\varrho^2}{\varrho'^3}\left(-3 \cos 2 v - 2 v'\right) =$			$\delta v =$ n^{-1}		
$\frac{171}{4}$	$m^2 e'$	$\cos g'$	-3		$\cos g'$
-3		,, 2τ	$-\frac{74}{3}$	$m^2 e'$	,, 2τ
$-\frac{21}{2}$	e'	,, $2\tau - g'$	$+\frac{215}{48}$	m^2	,, $2\tau - g'$
$+\frac{3}{2}$	e'	,, $2\tau + g'$	$-\frac{257}{48}$	m^2	,, $2\tau + g'$

(*Ante*, Annex 17).

and we have thence in $m^2 n^2 \delta Q$ the term

$$
\begin{array}{ll}
m^4 n e' & \frac{1}{2} . \ \frac{171}{4} . -3 \\
& +\frac{1}{2} . -3 \ . -\frac{74}{3} \\
& +\frac{1}{2} . -\frac{21}{2} . \ \frac{215}{48} \\
& +\frac{1}{2} . \ \frac{3}{2} \ . -\frac{257}{48}
\end{array}
$$

that is

$$\left(-\frac{513}{8} + 37 - \frac{1505}{64} - \frac{257}{64} =\right) - \frac{1749}{32} m^4 n e';$$

and, combining this with the other term just obtained, the two together are

$$\left(\frac{147}{16} - \frac{1749}{32} =\right) - \frac{1455}{32} m^4 n e';$$

and this term in $m^2 n^2 \delta Q$ gives in $m^2 n^2 (C + \int \delta Q\, dt)$ the term

$$- \frac{1455}{32} m^4 n e' t.$$

Annex 22.

Calculation of term in $-\frac{2}{\varrho} \frac{dv}{dt} \delta \varrho$.

We have

$-\frac{2}{\varrho}\frac{dv}{dt}$ (see Annex 19) $=$	$\varrho =$
$n \times$	
$-2 - \frac{1}{3} m^2$	$\left(\frac{3}{2} m^2 - \frac{1973}{32} m^4\right) e'\ t$
$+ 9 m^2 e' \quad \cos g'$	$+ \frac{3}{2} m^2 \quad t \cos g'$
$-\frac{15}{2} m^2 \quad ,, \ 2\tau$	$+ 5 m^2 e' \quad ,, \ 2\tau$
$-\frac{105}{4} m^2 e' \quad ,, \ 2\tau - g'$	$-\frac{7}{2} m^2 \quad ,, \ 2\tau - g'$
$+\frac{15}{4} m^2 e' \quad ,, \ 2\tau + g'$	$+\frac{1}{2} m^2 \quad ,, \ 2\tau + g'$

giving, besides the term $\frac{3}{2} m^2 n e' t$ already taken account of, the term

$$
\begin{array}{ll}
m^4 n e' t & + \frac{1973}{16} \cdot - \frac{1}{3} \cdot \ \ \frac{3}{2} \\
& + \frac{1}{2} \cdot \quad 9 \cdot \quad \frac{3}{2} \\
& + \frac{1}{2} \cdot - \frac{15}{2} \cdot \quad 5 \\
& + \frac{1}{2} \cdot - \frac{105}{4} \cdot - \frac{7}{2} \\
& + \frac{1}{2} \cdot \quad \frac{15}{4} \cdot \quad \frac{1}{2}
\end{array}
$$

which is

$$
= \left(\frac{1973}{16} - \frac{1}{2} + \frac{27}{4} - \frac{75}{4} + \frac{735}{16} - \frac{15}{16} \right) m^4 n^2 e' t
$$

$$
= \left(\frac{1973}{16} + \frac{275}{8} = \right) \frac{2523}{16} m^4 n^2 e' t.
$$

Annex 23.

Calculation of term in $\frac{m^2 n^2}{\varrho^2} (\mathrm{C} + \int \delta \mathrm{Q}\, d t)$.

We have

$$
\begin{array}{lll}
\frac{1}{\varrho^2} = & & \\
1 + \frac{1}{3} m^2 & & \\
\quad - 3\, m^2 e' & \cos g' & \\
\quad + 2\, m^2 & \ \ ,, \ 2\,\tau & \\
\quad + 7\, m^2 e' & \ \ ,, \ 2\,\tau - g' & \\
\quad - 1\, m^2 e' & \ \ ,, \ 2\,\tau + g' &
\end{array}
$$

$$
\begin{array}{lll}
m^2 n^2 (\mathrm{C} + \int \delta \mathrm{Q}\, d t) = & & \\
\quad n \times & & \\
- \frac{1455}{32} m^2 e' \ t & & \\
- \frac{15}{4} m^2 e' & t \cos 2\,\tau & \\
+ \frac{21}{8} m^2 e' & \ \ ,, \ 2\,\tau - g' & \\
- \frac{3}{8} m^2 e' & \ \ ,, \ 2\,\tau + g' &
\end{array}
$$

giving the term

$$
\begin{array}{ll}
m^4 n e' t & - \frac{1455}{32} \\
& + \frac{1}{2} \cdot \quad 2 \cdot - \frac{15}{4} \\
& + \frac{1}{2} \cdot \quad 7 \cdot \quad \frac{21}{8} \\
& + \frac{1}{2} \cdot - 1 \cdot - \frac{3}{8}
\end{array}
$$

which is

$$
= \left(- \frac{1455}{32} - \frac{15}{4} + \frac{147}{16} + \frac{3}{16} \right) = \left(- \frac{1455}{32} + \frac{45}{8} = \right) - \frac{1275}{32} m^4 n e' t,
$$

and this completes the series of calculations.

Printed by STRANGEWAYS and WALDEN, Castle St. Leicester Sq., and Published at the Apartments of the Society, May 10, 1862.

② MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. XXII.	*April* 11, 1862.	No. 6.

Dr. Lee, President, in the Chair.

Rev. J. Morton, Clifton;
J. F. Beckett, Esq., R.N.;
Rev. E. K. Elliott, Broadwater; and
N. Martindale, Esq., Holmfield, near Liverpool,

were balloted for and duly elected Fellows of the Society.

On a Re-discovery of the missing Lunar Crater, Alhazen, situated on the western border of the Mare Crisium. By W. R. Birt, Esq.

The Rev. T. W. Webb, in his interesting catalogue of lunar objects, speaks thus of this crater:—

"On the western edge of the *Mare Crisium*, Schröter delineated a crater, called by him *Alhazen*, which he employed to measure the existing libration: he saw in it, after a time, unaccountable changes; and now it is said it cannot be found. Beer and Mädler think he confounded it with a crater lying further south; the question, however, which, in the interim was debated between Kunowsky and Köhler, is not quite cleared up."

Having obtained a view, in January last, of *two* objects which appeared to me to have given rise to Schröter's remarks, I communicated my observations to Mr. Webb, and have lately received from that gentleman the following historical notices

of *Alhazen*, bearing especially on the variability of its aspect: —

"Schröter had watched and measured from it for years, and found it too varying in aspect to be accounted for by the varying angle of illumination. At first it was a depressed surface, surrounded by a ring, and distinguished from the neighbouring objects under all angles by its dark grey tint. Subsequently it often appeared, even in a 27-foot reflector (mirror about 20 inches), under favourable circumstances, as a bright longish flat mountain, though *more* frequently in its original grey aspect; occasionally it would be so indistinct, other objects being well defined, that he could not tell what to make of it. 1797, March 1, *Alhazen* being very near the limb (only $27''{\cdot}27$ from it), and therefore in a position to be very indistinct, especially as the terminator had advanced to the other side of the *Mare*, he saw it with a 13-foot reflector (mirror about 9 inches and power 180) more distinctly than ever, and in quite a new form, as a real, very deep, and bright crater, with an irregular ring scarcely united to the south, and open to the north, with a projection on the east side. Also there was a small shadow, as of a crater never seen before during the innumerable observations of ten years. Schröter thought *Alhazen*, under this aspect, appeared as deep as *Proclus*."

Mr. Webb enclosed a tracing, with this remark: — "I think you will consider it as affording an interesting comparison with your own observations. He has figured, you will see (as well as described), a little crater where you describe 'two (?).' The circumstance of his ranges uniting so closely to the south may be due to a different libration."

Kunowsky, in the *Astronomische Jahrbuch* for 1825, speaks of *Alhazen* as lost. In the *Jahrbuch* for 1826, Pastorff, writing January 20, 1823, says his son repeatedly found *Alhazen*. Pastorff also saw it (see p. 250 of the same *Jahrbuch*).

In the *Jahrbuch* for 1827 (p. 135), Harding is recorded as having seen *Alhazen* as Schröter had drawn it. Pastorff saw it in the same year, and in 1829.

The difference of aspect, as well as the occasional difficulty of finding this interesting spot, is highly curious. Schröter's earliest delineation gives it, as described, a shallow depression, *entirely* surrounded by a ring. My own observations, which now follow, may perhaps throw some light on these differences and difficulties. Two ranges of mountains, *one behind the other*, may easily be taken for a crater, and at a certain angle of illumination it may be exceedingly difficult to distinguish the difference. After a while the supposed crater entirely vanishes; libration alters the visual angle, and rotation the illuminating one, the observer being greatly puzzled as to what has become of his well-recognised crater.

1862, Jan. $3^d\,4^h\,45^m$ to $6^h\,0^m$, Moon's age $3^d{\cdot}1$, the termina-

tor passing through the *Mare Crisium* a little west of *Picard*, the floors of *Cleomedes*, *Burckhardt*, *Geminus*, and *Bernouilli* being in deep shadow, the *Promontorium Agarum* was very distinct, and in fine relief, and the craters *Condorcet*, *Hansen*, and *Alhazen* of Beer and Mädler exceedingly well marked; the *Alhazen* of Schröter also very distinct, and *Eimmart* between it and *Cleomedes* well seen.

Schröter's *Alhazen*, at first sight, appears to have somewhat the appearance of a crater, the west edge being high, but the east much lower. Upon attentively considering it, I have some reason to think that it consists of *two* nearly parallel ranges of mountains just on the borders of the *Mare*, the eastern range forming a part of the actual border. The shadow of the western range is (under this illumination) terminated at a line west of the eastern range, the western slope of which is glowing in bright sunshine. The mountain south of *Alhazen*, also figured by Schröter, is exceedingly distinct, and stands on the border of the *Mare*.

From the circumstance of not finding a distinct crater in this part of the border of the *Mare Crisium* when the evening shadows set in and the terminator sweeps over the western border of the *Mare*, combined with the surface of the *Mare* running in amongst the mountains on the west of the *Mare*, I am the more inclined to consider the appearance of a crater to be produced when the shadow of the western range falls short of the eastern.

1862, Jan. 4^{d} 5^{h} 30^{m} to 7^{h} 16^{m}, Moon's age $4^{d}\cdot 1$, terminator obliquely through *Atlas*. *Oersted*, *Cepheus*, *Franklin*, and *Berzelius*, with *Promontorium Archideum*, form a fine chain between *Atlas* and *Geminus*.

At times the definition has been very fine, and the real character of Schröter's *Alhazen* well seen; the southern termination of the two mountain-ranges was seen to be quite separate the one from the other, and the level surface passing between them. It is not surprising that the two combined should have been regarded as a crater, especially if viewed by a low power; for now, haze coming on, it is impossible to distinguish the two from a crater. In the earlier part of the evening the independence of the two ranges, especially on the south, was very apparent: the *shorter* shadow brought out very distinctly the *mountain* character, and the recess of the shadow of the eastern range revealed the existence of two (?) small craters lying at the foot of the eastern slope, upon the very border of the *Mare Crisium*. Beer and Mädler figure two mountain-ranges in the locality, but very unlike the mountain-ranges described above.

Note on a dark, circular Spot upon the Sun's Disk, with rapid motion, as observed by W. Lummis, Esq., of Manchester, 1862, *March* 20. By J. R. Hind, Esq.

In a letter addressed to me on the 20th of March, by W. Lummis, Esq., of the Manchester, Sheffield, and Lincolnshire Railway Company's Office at Manchester, it was stated that on the morning of the same day, while examining the Sun's disk with a telescope of about $2\frac{3}{4}$ inches aperture, he had remarked a small black spot more regular and better defined than usual. He watched it about 20 minutes, during which time it had moved rapidly, as shown in a diagram accompanying his letter, maintaining its *round* form : Mr. Lummis called a friend to see it, who remarked it as distinctly as himself.

On applying for further information with reference to his observation, Mr. Lummis wrote me, "As to the positions of the spot I regret that I cannot give them with much more precision than shown in the rough sketch sent to you, which was taken from one made at the time I witnessed the transit. I had no instrument but the telescope, and I measured with a small strip of card the distances of the spot from the Sun's edge. From the time when I first observed it, $8^h\ 28^m$ A.M., (Manchester time) to $8^h\ 50^m$, the spot had moved over about $12'$ of arc, as nearly as I can judge by the eye, and its size or rather apparent diameter I should take to be about $7''$. The telescope is $2\frac{3}{4}$ inches in aperture and magnifies 80 times. I had for several mornings been observing the Sun, which I noticed was particularly free from spots. Only one small one could be detected by me on the morning of the 20th, just below the spot marked A on the sketch.* I regret extremely having been compelled to leave before the object had completed its transit, as I should have wished to have witnessed its egress."

On carefully reading off from Mr. Lummis's sketch the differences of azimuth and altitude of the spot and Sun's centre, and converting them into differences of longitude and latitude, I find the following numbers,

G.M.T.		
March 19	$20^h\ 37^m$	Longitude of spot = Long. of $\odot - 2'{\cdot}4$ Latitude of spot = $+ 3'{\cdot}9$
,,	$20^h\ 59^m$	Longitude of spot = Long. of $\odot - 7'{\cdot}0$ Latitude of spot = $+ 5'{\cdot}5$

It is evident, from the sketch, that Mr. Lummis's estimate of the arc passed over during the twenty-two minutes he watched the spot, is much too great. It would be nearer $6'$ than $12'$.

In a letter dated 2d May, addressed to the Editor, Mr. Lummis writes that the spot appeared quite circular, and perfectly and sharply defined, and that the dimensions stated (viz. $7''$) may be regarded as a maximum measurement.

* The first position of the moving spot.

Considerations on the Solar Spots. By M. Eugene Jeanjaquet.

The author refers to his work, ***Phénomènes Célestes résultant de la Transmission successive de la Lumière***, published in 1859, as containing the following evident proof that the solar spots, whatever their nature may be, are not the appearances (*les aperçus*) of an obscure nucleus, situate in the centre of the photosphere, and consequently that there is no reason for believing in the existence of such a nucleus. "Si le soleil," he said, "était composé tout à la fois d'une noyau solide et d'une triple enveloppe gazeuse concentrique à ce noyau, si mince que fût cette enveloppe elle n'en augmenterait pas moins l'astre de son épaisseur; il y aurait par conséquent sur tout le pourtour du disque une bande circulaire sur laquelle aucune tache ne pourrait se montrer; en d'autres termes, ce n'est qu'à une certaine distance, en dedans du disque, que des taches pourraient se laisser voir. Or, les taches commencent et finissent avec les bords mêmes du soleil; donc elles ne sont pas des ouvertures dans le sein de l'atmosphère vraie ou fausse de l'astre de jour."

And, after illustrating this proof by a figure, he proceeds as follows:—

"Mais les taches solaires commencent-elles et finissent-elles réellement sur les bords de l'astre radieux? Il semble, tant la chose est suffisamment établie, que je pourrais me dispenser de faire cette question. Il s'en faut de beaucoup cependant que je ne doive pas la soulever. Suivant quelques observateurs, l'enveloppe solaire, dans l'hypothèse du globe central obscur, est excessivement peu épaisse; elle n'aurait de profondeur, d'après M. Secchi, que dans la minime proportion de quatre millimètres sur un globe d'un mêtre de rayon.* Il est vrai de dire que M. Secchi, tout en faisant l'enveloppe solaire si mince, ne prétend pas imposer de tous points sa manière de voir. Il déclare lui-même que son opinion n'a rien d'absolu, puisqu'elle est le résultat d'une seule observation, et qu'il existe probablement des ouvertures plus profondes que celle qui lui a servi de mesure. Quoiqu'il en soit, l'enveloppe aurait dans tous les cas très-peu d'épaisseur. Or, une aussi mince enveloppe, si elle existe, réporterait naturellement les taches très-près des bords du soleil, si près même de ces bords que leur lieu d'apparition et de disparition ne pourrait souvent être constaté qu'avec la plus grande peine; partant, que l'on n'aurait absolument aucune assurance qu'un globe solide ne se trouvé pas en définitive au centre de l'astre du jour. La question de savoir si véritablement les taches naissent et s'effacent sur les bords du soleil est donc discutable, et elle mérite certainement d'être discutée.

* *Astronomische Nachrichten*, No. 1148, p. 307.

"Puis, il y a une autre question, se rattachant à l'existence des taches aux extrêmités du disque solaire, qui mérite aussi d'être étudiée. Des entailles ont été vues occasionnellement sur le limbe du soleil, et ces entailles n'ont pas tardé à être suivies de taches. Est-ce que de semblables faits n'impliquent pas nécessairement des ouvertures dans une enveloppe, et au fond de ces ouvertures le corps intérieur de l'astre radieux?

"Je m'empresse de le dire; en ce qui touche la mince enveloppe du soleil, assez d'apparitions et de disparitions de taches ont été constatées pour qu'il ne puisse pas y avoir de doute sur le lieu où ces apparitions et disparitions s'opèrent. Ceux qui, depuis Galilée jusqu'à nos jours, ont longuement et patiemment examiné le soleil pour déduire du mouvement de ses taches le temps de sa rotation, ne nous auraient point donné le temps de cette rotation s'ils n'avaient pas vu des taches naître et mourir aux bords mêmes de l'astre lumineux. On ne lit dans les écrits d'aucun observateur que les taches commencent et finissent en dedans du limbe solaire, tandis qu'il n'est pas un auteur un peu compétent qui n'enseigne qu'elles apparaissent et disparaissent sur les bords mêmes de l'astre. Toutes nos connaissances sur le mouvement des taches seraient vaines, si les instants d'apparition et de disparition de ces étranges figures, aux limites extrêmes du soleil, ne nous étaient pas parfaitement connus. Que de choses, en revanche, ne saurions-nous pas sur le prétendu globe obscur, sur sa grandeur, sa distance à l'astre de lumière, etc. etc., si toutes les taches commençaient et finissaient en dedans du disque, à une distance des bords régulièrement la même! Nous ne savons pas ces choses, du moins nous ne les savons pas comme nous devrions les savoir; les taches ne se lèvent ni ne se couchent donc point, pour ainsi parler, à l'intérieur du disque solaire. Ainsi, on peut-être parfaitement tranquille, les taches apparaissent bien au bord oriental du soleil, et elles disparaissent bien à son bord occidental; rien n'est plus certaine que ce fait-là.

"Au surplus, des taches naîtraient et mourraient régulièrement à une certaine distance en dedans du disque du soleil (ce que les observations n'indiquent point, mais que j'admets ici un instant par voie de supposition), des taches, dis-je, naîtraient et mourraient régulièrement en dedans du disque solaire, à une courte distance des bords, que même une semblable circonstance, à moins que les taches ne fussent grandes, fortes, bien distinctes, ne serait nullement conclusive de l'hypothèse du globe central obscur, puis qu'on pourrait toujours objecter que les taches disparaissent par l'effet de l'éloignement: ne sait-on pas combien les noyaux se rapetissent à mesure qu'ils s'éloignent du centre du soleil, combien ils grandissent au contraire à mesure qu'ils s'approchent de ce centre?

"J'arrive aux entailles qui se voient occasionnellement sur les bords du soleil et qui ne sont naturellement autre chose que de fort grandes taches, tout noyau sur le limbe solaire y pro-

duisant nécessairement une échancrure. Si ces entailles se montrent en noir, on comprend que mon opinion s'en trouve fortifiée; et c'est bien en noir qu'elles se montrent. Mais il paraît qu'il y a à cette règle des exceptions et qu'en de certaines occasions, excessivement rares d'ailleurs, des entailles ont été vues béantes; c'est du moins ce qui semble surtout ressortir d'une grande échancrure que M. Lawson a observée le 30 Juin, 1846, sur le bord oriental du soleil, échancrure à laquelle une tache noire n'aurait pas tardé de faire suite. Une entaille béante suivie immédiatement d'une tache! Une ouverture photosphérique avec un noyau à sa base! Quelle plus grande preuve pourrait-on donner de l'existence d'un globe central obscur! Heureusement que pour répondre à cette formidable objection, nous avons l'exemple de la lune dans les éclipses de soleil. La lune aussi lorsqu'elle échancre le soleil, fait sur lui une entaille libre, et ce n'est jamais que lorsqu'elle le recouvre en entier qu'elle se révèle en *noir:* pourquoi un noyau de tache, s'avançant sur l'astre de lumière, ne se conduirait-il pas, toutes proportions gardées, de la même façon que notre satellite?* Ainsi, bien loin qu'une entaille béante indique une ouverture sur le bord de l'astre, on peut dire qu'une semblable échancrure est une preuve de plus de l'existence des taches aux extrêmes limites du disque du soleil."

"*Neuchâtel* (*Suisse*), le 28–30 Mars 1862."

On the Transit of Mercury of 12 *Nov.* 1861, *observed at Hobart Town.* By Mr. Abbott.

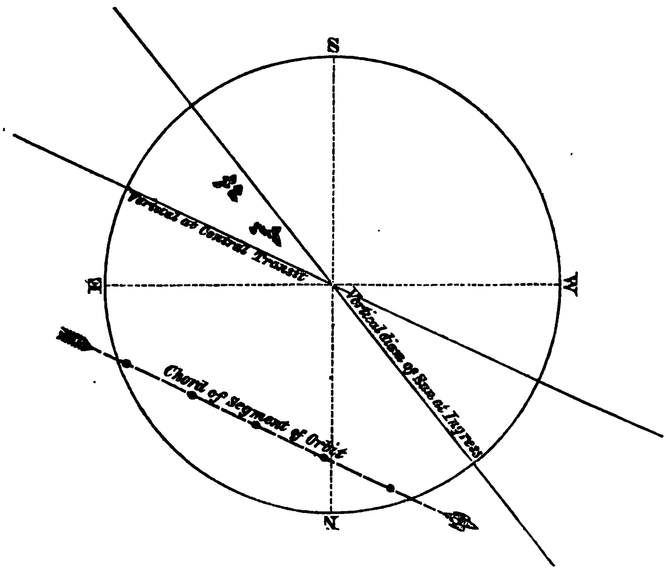
I transmit a diagram of the transit of *Mercury*, which occurred on the 12th of the present month. The time of ingress stated may not be quite as correct as I could have wished, from the following circumstances,—

To make sure of true time I had taken a transit at noon on the same day; on that point, therefore, I considered myself well prepared for the occasion.

A short time before the immersion, I had erected a 5-foot telescope on one of Varley's stands, and at the very point of the planet's contact, one of the bands gave way, which caused at that critical moment a slight confusion, until I could get the telescope tube remounted on a fresh stand; notwithstanding this accident I consider the time given a close approximation.

* "On n'a pas suffisamment fait attention, à mon avis, à tout ce qu'il y a de remarquable dans cette manière d'agir de la lune, parfaitement *invisible* tant qu'il reste une parcelle de lumière solaire, et, une fois le dernier filet de lumière supprimé, se montrant immédiatement en *noir*."

The afternoon on the whole was favourable, and had it not been for Mount Wellington (4240 feet high) blocking out our western horizon, the whole transit might have been seen, from ingress to egress.



Observed time of ingress for Hobart Town Mean Time.

	h	m	s	
Exterior contact.........	3	6	16	P.M.
Centre......................	3	8	25	,,
Interior contact	3	9	36	,,

Hobart Town, Tasmania, Nov. 25, 1861.

Results of Meridional Observations of Small Planets; Occultations of a Star by the Moon; and Phenomena of Jupiter's Satellites; observed at the Royal Observatory, Greenwich, during the month of March, 1862.

(*Communicated by the Astronomer Royal.*)

Flora ⑧.

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, Mar. 25	13 57 22·8	14 10 25·49	93 17 42·46

Metis (9).

Mean Solar Time of Observation.			R.A. from Observation.	N.P.D. from Observation.
		h m s	h m s	° ′ ″
1862, Mar.	4	9 40 33·9	8 30 6·85	62 15 40·00
	8	9 23 47·4	8 29 3·77	62 20 57·70
	10	9 15 37·0	8 28 45·12	62 24 38·50
	12	9 7 34·6	8 28 34·57	62 28 50·88

Eunomia (15).

Mean Solar Time of Observation.			R.A. from Observation.	N.P.D. from Observation.
		h m s	h m s	° ′ ″
1862, Mar.	4	9 16 54·2	8 6 23·29	76 1 7·76
	12	8 43 34·1	8 4 30·11	76 6 16·08

Psyche (16).

Mean Solar Time of Observation.			R.A. from Observation.	N.P.D. from Observation.
		h m s	h m s	° ′ ″
1862, Mar.	3	11 22 0·5	10 7 53·58	78 12 20·13
	4	11 17 19·9	10 7 8·72	78 7 30·69

Thalia (23).

Mean Solar Time of Observation.			R.A. from Observation.	N.P.D. from Observation.
		h m s	h m s	° ′ ″
1862, Mar.	3	11 50 45·8	10 36 43·55	60 38 39·90
	4	11 45 56·7	10 35 50·27	60 36 48·56

Amphitrite (29).

Mean Solar Time of Observation.			R.A. from Observation.	N.P.D. from Observation.
		h m s	h m s	° ′ ″
1862, Mar.	3	13 19 15·0	12 5 27·33	90 15 3·66
	25	11 32 37·2	11 45 16·15	88 58 46·20

All the observations of N.P.D. have been corrected for Refraction and Parallax.

March 9. The disappearance of 6 *Geminorum* at the Moon's dark limb was observed by Mr. Criswick to take place at 7^h 1^m $40^s·6$ mean solar time.

Phenomena of Jupiter's Satellites.

Day of Observation. 1862.	Satellite.	Phenomenon.	Mean Solar Time. h m s	Observer.
Mar. 4	III	Ecl. disapp.	14 38 34·5	T. C.
25	I	Egress, first cont.	8 38 41·9	C.
25	I	,, bisection	8 40 11·6	C.
25	I	,, last cont.	8 42 11·3	C.

The initials C. and T. C., are those of Mr. Criswick and Mr. Chappell.

Observations of Encke's Comet, taken with the Equatoreal of the Liverpool Observatory. By J. Hartnup, Esq.

Day.	G.M.T. h m s	Comet's R.A. h m s	Comet's N.P.D. ° ′ ″	Stars of Comparison.
1861, Dec. 1	7 20 17·0	22 25 2·79	83 21 1·3	ζ Pegasi.
5	7 4 3·9	22 22 32·99	83 57 41·8	,,
21	7 11 28·5	22 18 3·45	85 49 6·7	η Aquarii.
25	6 9 34·7	22 17 47·26	86 11 47·3	,,
28	6 4 37·2	22 17 38·68	86 28 50·7	,,
1862, Jan. 22	6 8 56·6	21 57 27·29	92 32 37·2	θ and η Aquarii.
25	6 8 5·2	21 47 20·09	94 45 10·4	α Aquarii.

The observations are corrected for Refraction and Parallax.

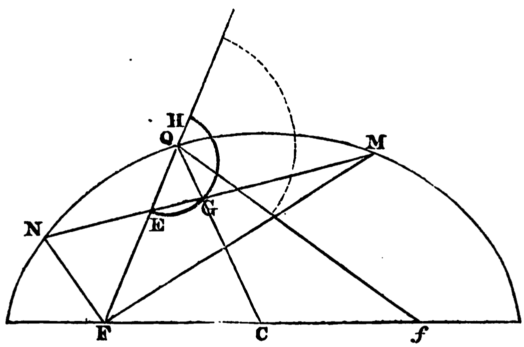
The places of the stars of comparison were taken from the *Nautical Almanac.*

On Lambert's Theorem for Elliptic Motion. By A. Cayley, Esq.

The theorem referred to is that which gives the time of description of an elliptic arc in terms of the radius vectors and the chord. The demonstration given by the author in his "Insigniores Orbitæ Cometarum Proprietates," Augs. 1761, depends upon a series of geometrical propositions of great elegance, which may be thus stated,

Let F Q be a line given in magnitude and position, E a given point on this line, Q f a line given in magnitude only, the position thereof being determined by assigning a value to

its variable inclination to the line F Q. With F, f, as foci describe an ellipse passing through the point Q (the axis major $= FQ + Qf$, is of course a constant magnitude). Take C,



the centre of the ellipse, and join C Q; through E draw a chord, M E N, conjugate to the diameter C Q and meeting it in G. Then treating the inclination as variable,

1°. The locus of G is a circle passing through E, and having its centre on the line F Q.

2°. The semichord G M or G N, and the sum $FM + FN$ of the radius vectors are respectively constant.

3°. The elliptic area N F M, divided by the square root of the latus rectum, is a constant.

It may also be mentioned, that taking 2θ to represent the external inclination (supplement of the angle FQf), and if, moreover, a is the semiaxis major, e the excentricity, and u, u' the excentric anomalies of the points M, N, then the square root of the latus rectum, or say $\sqrt{1-e^2}$, $\propto$ $\sin\theta$, and moreover E M, E N, F M, F N, $e\cos u$, $e\cos u'$, $e\sin u$, $e\sin u'$, consist each of them of a constant part, *plus* a part which $\propto$ $\cos\theta$; these expressions give as above $GM = GN = \frac{1}{2}(EM + EN) =$ constant, $FM + FN =$ constant; and they give moreover $e\cos u + e\cos u' =$ constant; $e\sin u - e\sin u'$ $=$ constant; $u - u' =$ const. The expression for the area is $\frac{1}{2}a^2\sqrt{1-e^2}\,\{u - u' - (e\sin u - e\sin u')\}$, and consequently the area divided by $\sqrt{1-e^2}$ is a constant; that is, the area is, as stated above, proportional to the square root of the latus rectum.

Hence, assuming the dynamical theorem that for a given central force at F, varying inversely as the square of the distance, the time of describing the elliptic arc is proportional to the area divided by the square root of the latus rectum, the time of describing the elliptic arc is constant. But in the extreme case, where the point f lies in the line F Q produced in

the direction from F to Q, the ellipse reduces itself to a finite right line, length $FQ + Qf$, which is considered to be described by a body falling from the extremity with an initial velocity zero; and the arc M N is a portion thereof given in magnitude, and having for its centre the point H (where E H is the diameter of the before-mentioned circle, the locus of G). Hence the time of describing the elliptic arc is equal to the time of describing, under the action of the same central force, a given right line, and as such it is at once obtainable in the form

$$\frac{a^{\frac{3}{2}}}{\sqrt{\mu}}\left(\phi - \phi' - (\sin\phi - \sin\phi')\right)$$

where ϕ, ϕ' are functions of the major axis $FQ + Qf$, and of F M, F N, or, what is the same thing, of $FQ + Qf$, and of the chord M N and sum of the radius vectors F M, F N. The preceding is the geometrical mode of getting out the result, without the assistance of any expression for the elliptic area, and latus rectum, and assuming only that we know the formula for rectilineal motion; but, if the expressions for the elliptic area and latus rectum are obtained, then the expression for the time is known, and the problem is solved, without the necessity of passing from the ellipse to the right line.

Writing $FQ = \varrho$, $QF = \sigma$, and as before the exterior angle of inclination $= 2\theta$, the actual expressions for the various lines of the figure are easily found to be

$$\frac{1}{2}(\varrho + \sigma) \qquad , = a$$

$$CF = Cf = \frac{1}{2}\sqrt{\varrho^2 + \sigma^2 + 2\varrho\sigma\cos 2\theta}, \quad = a$$

$$CQ \quad = \frac{1}{2}\sqrt{\varrho^2 + \sigma^2 - 2\varrho\sigma\cos 2\theta}, \quad (= a'$$

$$CR \quad = \sqrt{\varrho\sigma} \qquad , (= b'$$

where C R (not shown in the figure) denotes the semi-diameter conjugate to C Q.

$$1 - e^2 = \frac{4\varrho\sigma}{(\varrho + \sigma)^2}\sin^2\theta$$

$$\cos F = \frac{\varrho + \sigma\cos 2\theta}{2ae}, \quad \cos Q = \frac{\varrho - \sigma\cos 2\theta}{2a'},$$

$$\sin F = \frac{\sigma\sin 2\theta}{2ae}, \quad \sin Q = \frac{\sigma\sin 2\theta}{2a'}, \quad \sin C = \frac{\varrho\sigma\sin 2\theta}{4a'ae},$$

where F, C, Q, denote the angles of the triangle FCQ, respectively,

$$E\,G = \frac{2\,k\,\sigma}{\rho + \sigma}\cos\theta, \quad \text{and} \therefore E\,H = \frac{2\,k\,\sigma}{\rho + \sigma},$$

$$Q\,G = \frac{k}{\rho + \sigma}\,2\,a',$$

and, if for shortness $\Lambda = \sqrt{k\,\rho\,\sigma\,(\rho + \sigma - k)}$, then

$$(E\,M, E\,N) = \frac{2}{\rho + \sigma}(\Lambda \pm k\,\sigma\cos\theta),$$

$$(F\,M, F\,N) = \frac{1}{\rho + \sigma}\left\{\rho\,(\sigma + \rho) + k\,(\sigma - \rho) \pm 2\,\Lambda\cos\theta\right\},$$

so that

$$G\,M = G\,N = \frac{1}{2}(E\,M + E\,N) = \frac{2\,\Lambda}{\rho + \sigma},$$

$$\frac{1}{2}(F\,M + F\,N) = \qquad \frac{1}{\rho + \sigma}\left\{\rho\,(\sigma + \rho) + k\,(\sigma - \rho)\right\},$$

and moreover

$$(e\cos u, e\cos u') = \frac{1}{(\rho + \sigma)^2}\left\{(\sigma - \rho)\,(\rho + \sigma - 2\,k) \mp 4\,\Lambda\cos\theta\right\},$$

$$(e\sin u, e\sin u') = \frac{1}{(\rho + \sigma)^2}\left\{\pm\frac{2\,(\sigma - \rho)\,\Lambda}{\sqrt{\rho\,\sigma}} + 2\,(\rho + \sigma - 2\,k)\sqrt{\rho\,\sigma}\cos\theta\right\},$$

so that

$$e\cos u + e\cos u' = \frac{2}{(\rho + \sigma)^2}\,(\rho + \sigma - 2\,k),$$

$$e\sin u - e\sin u' = \frac{4}{(\rho + \sigma)^2}\,\frac{(\sigma - \rho)\,\Lambda}{\sqrt{\rho\,\sigma}},$$

$$u - u' = 2\tan^{-1}\frac{2\,\Lambda}{\sqrt{\rho\,\sigma}\,(\rho + \sigma - 2\,k)} = \sin^{-1}\frac{4\,\Lambda\,(\rho + \sigma - 2\,k)}{(\rho + \sigma)^2\sqrt{\rho\,\sigma}},$$

$$u - u' - (e\sin u - e\sin u') = \sin^{-1}\frac{4\,(\rho + \sigma - 2\,k)\,\Lambda}{(\rho + \sigma)^2\sqrt{\rho\,\sigma}} - \frac{4\,(\sigma - \rho)\,\Lambda}{(\rho + \sigma)^2\sqrt{\rho\,\sigma}}$$

which is

$$= \phi - \phi' - (\sin\phi - \sin\phi'),$$

if

$$1-\cos\varphi = \frac{1}{2a}(\mathrm{FM}+\mathrm{FM}+\mathrm{MN}) = \frac{2}{(\varrho+\sigma)^2}\{\varrho(\sigma+\varrho)+k(\sigma-\varrho)+2\Lambda\},$$

$$1-\cos\varphi' = \frac{1}{2a}(\mathrm{FM}+\mathrm{FN}-\mathrm{MN}) = \frac{2}{(\varrho+\sigma)^2}\{\varrho(\sigma+\varrho)+k(\sigma-\varrho)-2\Lambda\}.$$

In fact we then have also

$$1+\cos\varphi = \frac{2}{(\varrho+\sigma)^2}\{\sigma(\sigma+\varrho)-k(\sigma-\varrho)-2\Lambda\},$$

$$1+\cos\varphi' = \frac{2}{(\varrho+\sigma)^2}\{\sigma(\sigma+\varrho)-k(\sigma-\varrho)+2\Lambda\},$$

and thence

$$\sin\frac{1}{2}\varphi = \frac{1}{\varrho+\sigma}\left(\sqrt{\varrho(\varrho+\sigma-k)}+\sqrt{k\sigma}\right),\quad \sin\frac{1}{2}\varphi' = \left(\sqrt{\varrho(\varrho+\sigma-k)}-\sqrt{k\sigma}\right),$$

$$\cos\frac{1}{2}\varphi = \frac{1}{\varrho+\sigma}\left(\sqrt{\sigma(\varrho+\sigma-k)}-\sqrt{k\varrho}\right),\quad \cos\frac{1}{2}\varphi' = \left(\sqrt{\sigma(\varrho+\sigma-k)}+\sqrt{k\varrho}\right),$$

whence

$$\sin\varphi = \frac{2}{(\varrho+\sigma)^2}\left\{\sqrt{\varrho\sigma}(\varrho+\sigma-2k)+\frac{(\sigma-\varrho)\sqrt{\Lambda}}{\sqrt{\varrho\sigma}}\right\},$$

$$\text{in}\,\varphi' = \frac{2}{(\varrho+\sigma)^2}\left\{\sqrt{\varrho\sigma}(\varrho+\sigma-2k)-\frac{(\sigma-\varrho)\sqrt{\Lambda}}{\sqrt{\varrho\sigma}}\right\},$$

$$\text{and } \therefore\quad \sin\varphi-\sin\varphi' = \frac{4(\sigma-\varrho)\sqrt{\Lambda}}{(\varrho+\sigma)^2\sqrt{\varrho\sigma}},$$

$$\sin\frac{1}{2}(\varphi-\varphi') = \frac{2k\Lambda}{(\varrho+\sigma)\sqrt{\varrho\sigma}},\quad \cos\frac{1}{2}(\varphi-\varphi') = \frac{\varrho+\sigma-2k}{\varrho+\sigma},$$

$$\text{and } \therefore\quad \sin(\varphi-\varphi') = \frac{4(\varrho+\sigma-2k)\Lambda}{(\varrho+\sigma)^2\sqrt{\varrho\sigma}},$$

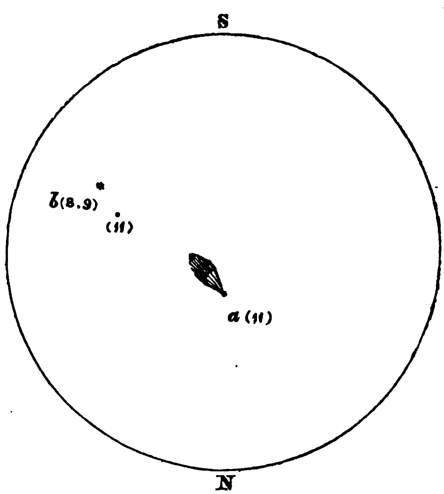
which verifies the formula.

On the missing Nebula in Taurus, on Comet II. 1861, *and on Mountain Attractions.* By M. O. Struve.

(Communicated by the Astronomer Royal.)

In the month of December we were informed by letters of Prof. d'Arrest's important observation, that the Nebula dis-

covered by Mr. Hind in the constellation of *Taurus* had disappeared. In the first favourable night, 1861, Dec. 29, we directed our large refractor upon the object, and in the first moment thought that its faintness exceeded even the power of our instrument; but, after some minutes, when the eyes had sufficiently adapted themselves to the darkness, we distinctly recognised some traces of nebulosity to the south of a star of 11th magnitude. Mr. Winnecke, whose assistance I had asked on this occasion, agreed with me entirely about the position of this nebulosity. The line joining it with the star of 11th magnitude made an angle of 15° f.f. with the line drawn from that star to another star of 11th magnitude, visible in the same field at a distance of 4′ south preceding. The distances of the brightest part of the Nebula from the first-mentioned star was estimated by me = 0·22, by Dr. Winnecke = 0·15 of the distance of the two stars, or about 50″. Since then we had for nearly three months' very unfavourable weather, and it was only in the night of March 22 that I thought there was a good opportunity for inspecting again that object. My expectation was not deceived. On the first glimpse the Nebula appeared considerably brighter than it did in December, so that it even bore a feeble illumination of the wires. On measuring the direction from the star *a* (see accompanying sketch), I found it 213°·2, while that of the star *b*, mag. 8.9, was 223°·6.



As the other small star which had served for comparison on Dec. 29, has nearly the same direction as *b*, this observation

confirms perfectly the estimation made on that former occasion. On March 22 I thought I could trace the nebulosity from the star *a* as far as one-third of the distance from *a* to *b*, or about 1′·7; but it was broader and more conspicuous nearer to *a*. There again it had the appearance as if on its extreme southern end there was a point of more concentrated light, which made the impression of being another extremely faint star, between which and the star *a* the Nebula extended the whole length. The sketch will give a general idea of what I saw. Also on this evening my observation was controlled by the sharp eye of Dr. Winnecke.

The facility with which I saw the Nebula in March, compared with the difficulty of the first observation, made upon me the impression as if in the interval the brightness of the Nebula had considerably increased; but this impression is probably in a great part due to the extraordinary transparency of the atmosphere we enjoyed in the month of March.

It will be remembered by the readers of the *Monthly Notices*, that my observations made in 1857 on the great Nebula of *Orion* had left with me the impression as if certain parts of its central region was subject to rapid changes of light. An extensive memoir containing the full account of my observations on this subject is nearly ready for distribution. It will be seen then that all the later observations have confirmed the first impression. The analogy between these observations and the recent discovery of Prof. d'Arrest is conspicuous; but a direct confirmation of my observation by an experienced observer established in a more southern position, and provided with sufficient optical means, is nevertheless very desirable. In this respect I hope Mr. Lassell's new expedition to Malta will afford results of a decisive character.

The extraordinary transparency of the atmosphere during the month of March afforded me the opportunity of making a series of observations of the great Comet of last year (II. 1861), which, I trust, will offer a good normal position for this epoch. These observations bear the date of March 20, 21, 22, 25, and 28; the first observation was made in my absence by Dr. Winnecke; the others by me.

In the present month I have got until now only one determination on April 16, but I hope to get some more observations before the moon returns. The next month the midnight twilight will be too bright in our northern latitude to allow any observation of such a faint object; but in southern climates it might be yet observed some weeks more. With this view I subjoin here an Ephemeris computed by Mr. Liasser from ten to ten days, for the months of May to August, which, in the hands of Mr. Lassell or Mr. Bond, might prove useful:—

0h Berlin M.T.	Comet's R.A. h m	Comet's Decl. ° ′	Log r.	Log Δ.
April 30	22 34·1	76 51·1	0·648	0·673
May 10	22 55·2	79 7·3	·657	·684
20	23 17·9	81 18·4	·667	·694
30	23 43·8	83 24·0	·676	·704
June 9	0 16·5	85 23·1	·685	·713
19	1 8·9	87 13·6	·694	·722
29	3 32·8	88 43·8	·702	·730
July 9	9 10·3	88 36·8	·710	·737
19	11 9·3	87 15·8	·718	·743
29	11 57·9	85 50·9	·726	·749
Aug. 8	12 29·6	84 21·8	·734	·754
18	12 56·1	83 9·0	0·741	0·758

This Ephemeris shows that about July 1 the Comet will approach the north pole within a degree, a circumstance that, it appears, will complicate a little the reduction of the observations, if such should succeed about that time.

In the month of August the nights will be here again sufficiently dark to admit a look-out for the Comet, though the hope of seeing it distinctly at that advanced period is rather small. At present the distance of the Comet from the Sun and Earth is about 4·5 (the same as the large Comet of 1811 had when it was rediscovered by Wisniewsky, in the summer of 1812); but in August it will be about 5·6. Hence it follows that, taking $\frac{1}{r^2 \Delta^2}$ for the coefficient of its light, this will be about 2·2 times less than it is now. On the other hand there is a strong suspicion, as already Prof. Schönfeld has pointed out, that the intensity of light of this Comet is subject to considerable variability, and this circumstance might, perhaps, favour a rediscovery. This suspicion has now some confirmation by my last observation. In one night it hardly bore any illumination of the field, while in other nights it could be distinctly seen even when the bright wire crossed it. But even in these nights I preferred using the method of celestial triangulation which rendered me such good service at the first appearance of Faye's Comet. On April 16 the diameter of the Comet was estimated about 40″. Its light is, even in its present faint state, not quite uniform, but shows distinctly traces of concentration.

Mr. Seeling's last elements of the Comet's orbit in No. 1347 of the *Astronomische Nachrichten*, which have served also for Mr. Liasser's Ephemeris, appears to be already very exact. A preliminary reduction of some observations has given the following differences:—

	C. – O. In R.A.	C. – O. In Decl.
	s	′
March 20	−6·6	+0·1
„ 21	−5·0	0·0
„ 22	−7·6	+0·4

Hence we must conclude that also the period of 419·5 years, assigned to this Comet by Mr. Seeling, is very nearly exact; but, of course, the last observations, and yet more those that might be made in the next months, will very efficaciously contribute to inclose the uncertainty of the period into narrower limits. This expectation will for itself be a sufficient stimulus for astronomers to spend some trouble on a most prolonged observation. But I think the interest attached to this Comet is yet considerably increased by the consideration that the observations made about the time of its greatest proximity to the Earth, if rigorously reduced, might well serve to deduce at least a confirmation, if not a possible correction, of the Sun's parallax. With this view a strict and critical examination of all existing observations and a most uniform and exact determination of all the comparison-stars would be a necessary condition of success. In the last part of the work the Observatory of Pulkowa will be glad to co-operate if there is only some prospect that any astronomers will undertake the laborious task of working out the results systematically.

Three weeks ago I received interesting news from General Chodzko, the Surveyor-general of our Caucasian provinces. This distinguished officer had been engaged last year with a junction of the triangles measured under his direction to the south of the Caucasus with the geodetic operation in the southern part of European Russia. The chain of triangles measured for this purpose crossed the Caucasian mountains almost at right angles, and I suggested to him the idea of using this favourable opportunity for collecting new and exact data concerning the attraction of large mountain masses. Accordingly General Chodzko selected six stations, situated on both sides of the mountain chain, upon which exact determinations of latitude were to be made. These stations were,

1. Tiflis, about 70 miles south of the central line of mountains.
2. Douchet, „ 35 „ „
3. Kobi, very nearly on the central line.
4. Wladikawkas, about 35 miles north of the central line of mountains.
5. Alexandrowskaja, „ 55 „ „ „
6. Mosdok, „ 70 „ „ „

On these stations the observations for latitude were executed by Capt. Oblomievsky, the designated Director of the

Observatory of Tiflis, which next year will begin its astronomical activity.

These observations were not yet entirely reduced when General Chodzko wrote me, and it will be particularly regretted that the results for the central station Kobi are not yet at hand. For the other stations General Chodzko gives the following results, which will be exact within a second. Supposing the latitude of Tiflis to be not affected by local attraction, and designing by φ the latitude as determined by direct astronomical observations on each station, and by φ' the latitude of the same station when deduced geodetically from that of Tiflis, with Bessel's elements of the Earth's figure, we have

For Douchet $\varphi' - \varphi =$	$+25''\cdot 1$
Wladikawkas	$-28\cdot 6$
Alexandrowskaja	$-12\cdot 0$
Mosdok	$-\ 5\cdot 6$

Whoever knows a little the geography of the country will agree that it is much more probable that Mosdok is less affected by local attraction than Tiflis. Therefore, attributing the whole amount of $\varphi' - \varphi$, as found for Mosdok, to the effect of local attraction on the direction of the plumb-line at Tiflis, we shall have

For Tiflis $\varphi' - \varphi =$	$+\ 5''\cdot 6$
Douchet	$+30\cdot 7$
Wladikawkas	$-23\cdot 0$
Alexandrowskaja	$-\ 6\cdot 4$

The latitudes of Douchet and Wladikawkas being respectively $42^\circ\ 5'$ and $43^\circ\ 1'$, we have here as the effect of mountain attraction, on an arc of only $56'$, a difference between the geodetic and astronomical arc of not less than $53''\cdot 7$; and the diminution of the quantity for Tiflis and Alexandrowskaja shows that the effect, as it ought to be, is there less approximately in proportion of the square of the distance from the principal chain of mountains. How far those differences answer the real attraction of the mountain masses will be the object of future inquiries, but even now it might be presumed that the result for the Caucasus will stand in some degree at variance with that obtained by the Indian triangulation for the Himalaya; so that the ingenious hypothetical explanation given by Mr. Airy for the apparent defect of attraction in those mountains will hardly meet with a satisfactory confirmation in the special case of the Caucasus. I have no doubt General Chodzko will continue these interesting researches with all the power he can command, and thereby furnish most precious results both for

geodesy and geology. Similar operations will be conducted by Prof. Schweizer in the neighbourhood of Moskwa (? Ed.), where it has been established by his preliminary researches that on an arc of 16′ the geodetic differences of latitude are greater by 18″ than the astronomical, and that these differences follow such a law as indicates a comparative defect of attracting matter, probably at some distance below the Earth's surface. Mr. Schweizer's preliminary researches will be published in a very short time.

Pulkowa, April 19th, 1862.

M. Struve has finally retired from the Presidency of the Observatory of Pulkowa; and it will be satisfactory to the Society to learn that M. Otto Struve has been officially appointed as his successor.

Letter from Sir John Herschel to Mr. Hind on the Disappearance of a Nebula in Coma Berenices.

(*Communicated by permission of Sir John Herschel.*)

I have met with another instance of the disappearance of a well-authenticated Nebula, which I think will interest you.

In M. d'Arrest's *Resultate aus Beobachtungen der Nebelflecken und Sternhaufen — Erste Reihe*, communicated to the *Royal Saxon Society of Sciences*, and printed in their *Transactions*, occur observations of two Nebulæ which M. d'Arrest considers as new, and sets down as "*novæ*," their places for 1850 being respectively

$$\left.\begin{array}{c} 185^\circ\,33'\,21''\!\cdot\!5 = 12^h\,22^m\,13^s\!\cdot\!4 \text{ R·A.} \\ 75^\circ\,44'\,32''\!\cdot\!5 \text{ N.P.D.} \end{array}\right\}\text{(A)}$$

and

$$\left.\begin{array}{c} 185^\circ\,40'\,16'' = 12^h\,22^m\,41^s\!\cdot\!0 \text{ R.A.} \\ 75^\circ\,32'\,2''\!\cdot\!0 \text{ N.P.D.} \end{array}\right\}\text{(B)}$$

(A)'s place is determined by two well-agreeing observations, and it is described as being bright, a 1st-class Nebula, round, 50″ in diameter, brighter in the middle to a star 10 mag.

(B)'s place by a single observation — very bright, 1st class, 50″ in diameter, round, brighter in the middle; a star 11 mag.

precedes $24^s.6$ nearly in the parallel; the place not very exact, but the nebula *frequently seen since in that place.*

No mention is made of any companion-nebula in the same field of view; and M. d'Arrest is so good an observer that any such, of equal or nearly equal brightness, would assuredly, on all these several occasions, not have escaped him.

Both M. d'Arrest's Nebulæ, *and one more*, of an order o brightness little inferior to the latter (B), occur in Sir W. Herschel's catalogues, (A) being identified with H. II. 114, and (B) with one of the two, H. II. 115 and II. 116.

The place of H. II. 114 for 1850 is settled by two observations in sweeps 187 and 199, made on April 8th and 17th, 1784. In the former it is stated to follow 6 *Comæ* $13^m.9 = 13^m\ 54^s$ in time, and to be $1^\circ\ 30'$ south of that star; in the latter to precede 34 *Virginis* $16^m.9 = 16^m\ 54^s$ in time, and to be $1^\circ\ 28'$ north of it. These give respectively, for its place for 1850,

	h m s		° ′ ″	
	12 22 16·9		75 45 33	
	12 22 46·5		75 45 16	
Mean	12 22 31·7	R.A.	75 45 34	N.P.D.

Of the identity of this with (A) there can, therefore, be no doubt.

Of H. II. 115 and 116 there occur also two observations in sweeps 187 and 691, made on the 8th of April, 1784, and 14th of January, 1787. In the former they are described thus:—"Two resolvable Nebulæ; they follow the 6th *Comæ* 14^m in time, and are $1^\circ\ 17'$ more south." In the latter they are described separately: the preceding as "very bright, considerably large, follows 6 *Comæ* $13^m\ 50^s$, south of it $1^\circ\ 19'$;" the following as "pretty bright, pretty large, follows 6 *Comæ* $14^m\ 5^s$, south of it $1^\circ\ 22'$."

It is certain therefore that both these Nebulæ were seen in the same field of view (for, when so paired together, such was invariably Sir W. Herschel's practice) on two occasions three years apart, so that neither was a comet; and by the second observation their respective situation was

$$\Delta\ \text{R.A.} = +\ 15^s, \qquad \Delta\ \text{N.P.D.} = +\ 3';$$

so that, supposing the place assigned in the first observation to refer to the middle point between them, we have their places,—

By observation 1st,

		h m s		° ′ ″
II. 115	R.A.	12 22 15·4	N.P.D.	75 30 33
II. 116	,,	12 22 30·4	,,	75 33 33

and by observation 2d,

II. 115	R.A.	$12^h\ 22^m\ 12^s.9$	N.P.D.	$75°\ 34'\ 53''$
II. 116	„	12 22 27·9	„	75 37 53

and taking the means,

II. 115	R.A.	12 22 14·1	N.P.D.	75 32 43
II. 116	„	12 22 29·1	„	75 35 43

The middle point between which differs from the place of (B) by only $19^s.4$ in R.A. and $2'\ 11''$ in P.D.; so that it is very certain that, had both the objects remained in their places, they must have been in the field of view of a telescope directed on (B).

M. d'Arrest's telescope has amply sufficient power to have shown the missing Nebula (the fainter of the two in all probability, or H. II. 116), which had sufficient illumination to be characterised as "resolvable," and as "pretty bright," or a full second-class Nebula.

Most unfortunately I find no observations of either of these Nebulæ in my reviews of the Nebulæ. They occur in a very rich region of the heavens; but by taking 6 *Comæ* as a guide, there can be no difficulty in setting a telescope upon the place; and I strongly recommend the point for re-examination.

Collingwood, April 4th, 1862.

Opposition of Mars, 1862. By Lieut. J. M. Gilliss, Director of the U.S. Naval Observatory, Washington.

The co-operation of astronomers is invited in a series of observations upon the planet *Mars*, near the opposition of the present year. Differential measures with the stars designated in the accompanying Ephemeris, will be made at the U. S. Naval Observatory, from 27th August to 7th November, 1862. They will be commenced at one hour before the transit of the planet over the meridian of Washington, and be continued during two hours, the measures being repeated as frequently and as rapidly as is consistent with the utmost care. The comparisons will be confined exclusively to the star selected for the night, and it will be referred to the north and south limbs of the planet at alternate measures, the time at which the planet's limb is observed being noted to the nearest tenth of a second. Both objects will also be observed with the meridian instruments, and their difference of declination will be measured with the micrometer-screw of the circle-telescope.

Astronomers who make these observations are most respectfully requested to forward a copy of them to this establishment as soon thereafter as is practicable, and to transmit, at the same time, a statement respecting the instruments used, together with any information which may influence a discussion of the results.

In preparing the Ephemeris, whenever suitable ones could be obtained, stars were selected from published catalogues, the criterion of availability being a difference of declination not to exceed 4′. For September 17th, it was necessary to take a more distant star. The places of those to which numbers only are given (1 to 11 inclusive) were derived from special observations made with the Washington Equatoreal. To facilitate recognition of the comparison-star selected for each night, all the stars contained in accessible Catalogues and Star-charts which lie near the path of the planet have been inserted on a map accompanying the Ephemeris.

A copy of this last, with the map, will be sent to every Observatory by mail. As some of the copies may not reach their destination, extra numbers will be forwarded to the Secretary, Royal Astronomical Society, London, and to Dr. C. A. F. Peters, at Altona, either of whom will furnish them on application.

Ephemeris of Stars to be observed with Mars near the Opposition of the Planet, 1862.

Date.	Object.	Mag.	α.	δ.
1862.			h m s	° ′ ″
Aug. 27	Mars		1 17 30	+3 5 43
	Weisse I. 335	9	20 27	9 43
28	Mars		1 17 45	3 6 48
	Weisse I. 335	9	20 27	9 43
29	Mars		1 17 58	3 7 37
	Weisse I. 335	9	20 27	9 43
30	Mars		1 18 6	3 8 12
	Weisse I. 335	9	20 27	9 43
31	Mars		1 18 12	3 8 22
	Weisse I. 335	9	20 27	9 43
Sept. 1	Mars		1 18 14	3 8 37
	Weisse I. 335	9	20 27	9 43
2	Mars		1 18 13	3 8 28
	Weisse I. 335	9	20 27	9 43

Date.	Object.	Mag.	α.	δ.
1862.			h m s	° ′ ″
Sept. 3	Mars		1 18 9	3 8 5
	Weisse I. 335	9	20 27	9 43
4	Mars		1 18 2	3 7 27
	Weisse I. 335	9	20 27	9 43
5	Mars		1 17 51	3 6 36
	Weisse I. 330	8.9	20 9	5 26
6	Mars		1 17 37	3 5 30
	Weisse I. 330	8.9	20 9	5 26
7	Mars		1 17 19	3 4 12
	Weisse I. 330	8.9	20 9	5 26
8	Mars		1 16 58	3 2 39
	Weisse I. 330	8.9	20 9	5 26
9	✱ 1	9	1 15 37	3 3 55
	Mars		16 35	0 54
10	✱ 2	9.10	1 12 38	2 58 47
	Mars		16 7	58 55
11	✱ 2	9.10	1 12 38	2 58 47
	Mars		15 37	56 45
12	✱ 2	9.10	1 12 38	2 58 47
	Mars		15 4	54 22
13	✱ 3	9.10	1 12 28	2 49 50
	Mars		14 27	51 48
14	Mars		1 13 48	2 49 2
	Weisse I. 229	9	15 11	47 49
15	Mars		1 13 5	2 46 6
	Weisse I. 229	9	15 11	47 49
16	Mars		1 12 19	2 42 59
	Weisse I. 229	9	15 11	47 49
17	Mars		1 11 31	2 39 43
	B.A.C. 397	7.8	12 16	33 48
18	Mars		1 10 40	2 36 18
	B.A.C. 397	7.8	12 16	33 48
19	Mars		1 9 46	2 32 45
	B.A.C. 397	7.8	12 16	33 48

Date. 1862.	Object.	Mag	α. h m s	δ. ° ′ ″
Sept. 20	Mars		1 8 50	2 29 4
	B.A.C. 397	7.8	12 16	33 48
21	Mars		1 7 51	2 25 16
	✱ 4	9	10 17	22 36
22	Mars		1 6 51	2 21 23
	✱ 4	9	10 17	22 36
23	Weisse I. 20	9	1 3 7	2 15 40
	Mars		5 48	17 25
24	Weisse I. 20	9	1 3 7	2 15 40
	Mars		4 43	13 23
25	Mars		1 3 36	2 9 18
	✱ 5	9	6 5	11 50
26	✱ 6	9	1 2 4	2 2 20
	Mars		2 28	5 11
27	Mars		1 1 19	2 1 2
	✱ 6	9	2 4	2 20
28	Weisse 0·1031	9	0 59 0	1 53 35
	Mars		1 0 8	56 54
29	Mars		0 58 57	1 52 47
	Weisse 0·1031	9	59 0	53 35
30	Mars		0 57 44	1 48 41
	Weisse 0·1023	9	58 36	44 11
Oct. 1	Mars		0 56 31	1 44 39
	Weisse 0·1023	9	58 36	44 11
2	Mars		0 55 17	1 40 39
	Weisse 0·973	9	55 50	36 10
3	Mars		0 54 4	1 36 44
	Weisse 0·973	9	55 50	36 10
4	Mars		0 52 50	1 32 54
	Weisse 0·973	9	55 50	36 10
5	✱ 7	9	0 48 34	1 32 19
	Mars		51 36	29 10
6	Mars		0 50 23	1 25 34
	Weisse 0·871	8.9	50 36	20 46

Date.	Object.	Mag.	α.	δ.
1862.			h m s	° ′ ″
Oct. 7	Mars		0 49 10	1 22 5
	Weisse 0ʰ871	8.9	50 36	20 46
8	Mars		0 47 58	1 18 45
	Weisse 0ʰ871	8.9	50 36	20 46
9	Mars		0 46 46	1 15 34
	✱ 8	9	49 38	17 0
10	Mars		0 45 36	1 12 33
	Weisse 0ʰ806	9	46 34	9 38
11	Mars		0 44 26	1 9 42
	Weisse 0ʰ806	9	46 34	9 38
12	Mars		0 43 18	1 7 3
	Weisse 0ʰ806	9	46 34	9 38
13	Weisse 0ʰ649	8	0 38 0	1 3 20
	Mars		42 11	4 35
14	Weisse 0ʰ649	8	0 38 0	1 3 20
	Mars		41 6	2 10
15	Weisse 0ʰ649	8	0 38 0	1 3 20
	Mars		40 3	0 19
16	Lalande 1123	9	0 35 35	0 56 24
	Mars		39 2	58 31
17	Lalande 1123	9	0 35 35	0 56 24
	Mars		38 2	56 57
18	Lalande 1123	9	0 35 35	0 56 24
	Mars		37 5	55 38
19	Lalande 1123	9	0 35 35	0 56 24
	Mars		36 10	54 35
20	Mars		0 35 17	0 53 47
	Lalande 1123	9	35 35	56 24
21	Mars		0 34 27	0 53 15
	Lalande 1123	9	35 35	56 24
22	Mars		0 33 40	0 52 59
	Lalande 1123	9	35 35	56 24
23	Mars		0 32 55	0 52 59
	Lalande 1123	9	35 35	56 24

Date.	Object.	Mag.	α.	δ.
1862.			h m s	° ′ ″
Oct. 24	Mars		0 32 13	0 53 17
	Lalande 1123	9	35 35	56 24
25	Mars		0 31 34	0 53 51
	Lalande 1123	9	35 35	56 24
26	Mars		0 30 57	0 54 43
	Lalande 1123	9	35 35	56 24
27	Mars		0 30 24	0 55 51
	Lalande 1097	8.9	34 30	59 34
28	Mars		0 29 53	0 57 17
	Lalande 1097	8.9	34 30	59 34
29	Mars		0 29 26	0 58 59
	Lalande 1097	8.9	34 30	59 34
30	Mars		0 29 2	1 0 59
	* 9	9	29 40	5 34
31	Mars		0 28 40	1 3 15
	* 9	9	29 40	5 34
Nov. 1	Mars		0 28 22	1 5 48
	* 9	9	29 40	5 34
2	Mars		0 28 7	1 8 38
	* 9	9	29 40	5 34
3	* 10	9.10	0 27 44	1 10 0
	Mars		27 54	11 44
4	* 11	9.10	0 26 52	1 16 40
	Mars		27 45	15 6
5	Weisse 0^{h}393	9	0 24 21	1 22 28
	Mars		27 39	18 44
6	Weisse 0^{h}393	9	0 24 21	1 22 28
	Mars		27 36	22 38
7	Weisse 0^{h}420	9	0 25 34	1 23 53
	Mars		27 36	26 47

U.S. Naval Observatory,
March 1862.

On the Minor Planet Feronia (71).* By Dr. C. H. F. Peters.

The observations made at the Hamilton College Observatory upon *Maja*, as it was supposed (see Brünnow's *Ast. Not.*, No. 27), from the 29th of May, belong, as Mr. Truman H. Safford has found, to another planet hitherto unknown. Having received, by the kindness of Professor Bond, the places of the comparison-stars from the *Harvard Zones*, not yet printed, I have been enabled to complete the reduction of the eight positions obtained between the 29th of May and 13th of June, and I have computed the following orbit for the new planet:—

Epoch, 1861, Jan. 0·0 Washington M.T.

	° ′ ″	
M_0	211 50 4·27	
π	317 39 5·63	Mean Equinox of Epoch.
☊	207 56 24·36	Mean Equinox of Epoch.
i	5 21 58·33	Mean Equinox of Epoch.
ϕ	7 0 15·84	
μ	1086″·924	
Log a	0·3425384	

The semi-axis major appears to be the smallest known of the asteroids, even a little smaller than that of *Flora*; which relation, however, of course is liable to be changed by further observations. The elements were derived from May 30, June 7, and June 13, with regard to the smaller corrections, and represent the whole series as follows:—

	Observed R.A. ° ′ ″	C—O. ″	Observed Decl. ° ′ ″	C—O. ″
May 29	176 39 11·5	+3·2	+0 36 12·8	+2·2
30	176 47 34·2	+0·1	35 8·3	+0·3
31	176 56 15·6	−2·8	33 50·4	+1·4
June 1	177 5 18·6	−3·4	32 22·2	+1·6
7	178 6 27·6	+0·3	20 0·2	+0·5
8	178 17 41·4	−3·2	17 25·2	−0·9
10	178 41 14·6	+1·2	11 39·6	−1·7
13	179 18 35·1	0·0	+0 1 54·7	−0·1

The remaining errors are perhaps not larger than may be expected of observations by the ring-micrometer, and upon an object of about 13th magnitude; part of the differences, besides, may be owing to the star-positions. On May 31 and June 1, for example, the same comparison-star was used. The observation on May 29 is not very good; only few comparisons could be obtained.

* See p. 170, where the Planet is called (72). *Feronia* being (71), *Niobe* will be (72).—Ed.

In opposition the planet will appear of about the 11th magnitude; and there will be, therefore, no difficulty to find it again on or before the next one, which will happen in September.

At my request Mr. Safford has selected the name; and the number ought to be (71), in accordance with the date of the first observation.

In the *Comptes Rendus* (6 Jan., 1862) there is contained an article by M. Leverrier, "On the System of the Planets *Mercury*, *Venus*, the *Earth*, and *Mars*," giving a survey of his researches, as consisting of the three distinct parts, a new examination of the theories, a new discussion of the observations, and lastly, the comparison of the theories and observations. The provisionally assumed masses were

$$\text{Mercury} \quad m = \frac{1+\nu}{3000000}$$

$$\text{Venus} \quad m' = \frac{1+\nu'}{401847}$$

$$\text{The Earth} \quad m'' = \frac{1+\nu''}{354936}$$

$$\text{Mars} \quad m''' = \frac{1+\nu'''}{2680337}$$

ν, ν', ν'', ν''' being quantities to be determined.

But to make the results of the theory agree with the observations it would be necessary to attribute to these quantities values which are altogether inadmissible. For instance, the discussion of the secular variation of the perihelion of *Mercury* leads to the equation $87'' \nu'' = +45'', 5$, or the mass of the Earth would require to be increased by nearly one-half its value, and it thus becomes necessary to explain the greater part of the excess of the observed motion of the perihelion of *Mercury* by some extraneous action.

The serious difficulties which present themselves in the motion of the four planets, reduce themselves to the three principal ones; 1°, the excess of the motion of the perihelion of *Mars*; 2°, the excess of the motion of the node of *Venus*; 3°, the excess of the motion of the perihelion of *Mercury*.

The first two difficulties appear to arise from the same cause, the one and the other would be removed by an increase in the mass of the Earth, and this would indicate a perturbing cause placed between the two planets *Venus* and *Mars*. But, M. Leverrier asks, does it follow that the mass of the Earth must really be augmented, or may not the disturbing mass (the action of which should be about equal to a tenth

part of the mass of the Earth) be detached from the Earth, and in this case in what manner is it distributed?

Among the objections, which seem not to permit the necessary addition to be made to the mass of the Earth, is the following; viz., an increase of one-tenth part in the mass of the Earth would disturb the relation that exists between the force of gravity at the surface of the Earth, the mass of the Earth, and the solar parallax, unless the solar parallax were increased by one thirtieth part.

The difficulties disappear by admitting that the perturbing mass is distributed among a considerable number of asteroids, such as exist between *Mars* and *Jupiter*, and whereof only the largest, it is probable, are observed; or such as observation shows to exist at a distance sensible equal to that of the Earth. Such a system of corpuscules would act especially on the perihelion of a planet having a considerable excentricity, and would give it a direct motion; it would less affect, or would not affect at all, the excentricity. It would be therefore, in the motion of the perihelion, attributed exclusively to the terms in the formulæ not depending on the longitude of this element, that a result can be obtained as to the total mass of these corpuscules.

But there is no means of deciding how much of the action is to be attributed to the group at the same distance as the Earth, and how much to the group between *Mars* and *Jupiter*. All that can be done is to assign superior limits to the masses of these groups respectively, by attributing to each of them successively the whole excess in the motion of the perihelion of *Mars*.

Assuming that the perihelia of the disturbing masses are uniformly distributed as to longitude, the results are,—

1°. If the whole excess in the motion of the perihelion of *Mars* is attributed to a ring of asteroids situate at a distance from the Sun equal to that of the Earth, the total mass of these asteroids will be somewhat greater than that of *Mars*, and will be equal to the fraction 0·138 of the mass of the Earth.

2°. If the whole excess is attributed to a group of asteroids between *Mars* and *Jupiter* (distance from the Sun between 2·20 and 3·16) the total mass of the group will be about one third of that of the Earth.

It is now, M. Leverrier thinks, established (*il reste acquis*) that it is not possible to represent all the observations of the system of the four inferior planets, by taking account only of their mutual actions and that of the Sun. But, at least, the difficulties are recognised and circumscribed in such manner that their solution cannot but be obtained, since astronomers now know the direction in which their efforts are to be made. On the one hand, the excess of the motion of the perihelion of *Mercury* is to be accounted for; and if the change of the

obliquity of the equator, deduced from the observations, be accepted, it is necessary to have recourse to the action of an extraneous and hitherto unknown cause. On the other hand, the analogous excess in the motion of the perihelion of *Mars* is to be accounted for; and, if the value of the solar parallax, deduced from the transits of *Venus*, be accepted, recourse must again be had to the action of an extraneous cause.

Disregarding the exceptional facts, and preserving the solar parallax $8''\cdot58$, the masses are definitively found to be,

$$\begin{array}{lll} \text{Mercury} & m & = \dfrac{1}{4348000} \\ \text{Venus} & m' & = \dfrac{1}{412150} \\ \text{The Earth} & m'' & = \dfrac{1}{354030} \\ \text{Mars} & m''' & = \dfrac{1}{2968300} \end{array}$$

which are the values adopted in M. Leverrier's tables.

Captain Shea continues to communicate to the Society his Observations of Solar Spots, now extending over a period of 15 years.

Mr. Samuel Sharpe, of Highbury Place, has presented to the Society a 10-inch Reflecting Circle, by Troughton, with its counterpoise stand.

RECENT PUBLICATIONS.

Astronomische Beobachtungen auf der Sternwarte zu Bonn. Von Dr. Fr. W. A. Argelander. Dritter Band, Bonner Sternverzeichniss, Erste Section. Bonn, 1859. Vierter Band, Bonner Sternverzeichniss, Zweite Section, Bonn, 1861.

The first section contains the approximate mean places of 110984 stars between the declinations 2° south and 20° north, for the beginning of the year 1855; the second section the approximate mean places of 105075 stars between 20° and 41° north declination for the same epoch, observed and calculated with the co-operation of Dr. E. Schönfeld and Dr. A. Kruger, by Dr. Argelander, Director of the Observatory.

An account of the progress of this great work of the Survey of the Northern Hemisphere, communicated by the direction of Dr. Argelander, has recently appeared in the *Monthly Notices*, see the December number, p. 57.

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Printed by Strangeways and Walden, Castle St. Leicester Sq. and Published at the Apartments of the Society, May 10, 1862.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXII. *May* 9, 1862. No. 7.

Dr. LEE, President, in the Chair.

S. H. Miller, Esq., Wisbeach;
Rev. J. E. Cross, Appleby, near Brigg, Lincolnshire; and
John Newton, Esq., Well Street,

were balloted for and duly elected Fellows of the Society.

J. S. S. Glennie, Esq., was balloted for and re-elected a Fellow of the Society.

Announcement of New Instruments about to be supplied by Government to the Great Trigonometrical Survey of India. By Lieut.-Colonel A. Strange.

It may interest the Society to be informed that the more purely scientific operations of the Great Trigonometrical Survey of India are about to receive an impulse by the addition of several important Instruments, namely,—

1 Great Theodolite, with a 3-feet Horizontal Circle.
2 Zenith Sectors.
3 Transit Instruments.
3 Astronomical Clocks.
3 Galvanic Registers.

Negotiations for the supply of these Instruments are now in progress, and the Secretary of State for India in Council has done me the honour to intrust the superintendence of their construction to me.

I have been engaged for a considerable period in preparing the design for the Great Theodolite, the working drawings of which, in nine large sheets, and a voluminous specification, are now completed, and embrace the most minute details. Though

based on brief notes by Sir Andrew Scott Waugh, the late Surveyor-General of India, and practically carried out by me, this design comprehends the suggestions of many minds. The endeavour has been to engraft on the excellencies of existing theodolites of the first class, all that the experience of thirty years or more has shown to be desirable, and modern science has rendered possible of achievement, for increasing the power, efficiency, and convenience of the new Instrument. It will present some features of novelty and value sufficient perhaps from time to time to engage the interest of the Society.

The form, size, and arrangements of the other Instruments above enumerated, are still under consideration.

Major J. T. Walker, of H. M. Indian Engineers, the present able Superintendent of the Great Trigonometrical Survey, proposes to employ the Zenith Sectors for adding to the number of points on the Great Meridional Arc of India, the latitudes whereof have been astronomically determined. At present there exist in the northern and more modern portion of this Arc, executed by Sir George Everest, only three such points in an extent of $11^{\circ}\ 28'$, subdividing the entire Arc into two sections whose amplitudes are respectively $5^{\circ}\ 24'$ and $6^{\circ}\ 4'$. Sir Henry James, Superintendent of the Ordnance Survey of Great Britain, suggests that an observed latitude at every degree "would have added very greatly to the weight of the determination of the Earth's figure, and would, besides, have thrown much light upon the question of Himalayan influence." The same object will probably lead Major Walker to use these instruments wherever facilities for doing so profitably are afforded by the extensive and accurate triangulation now spread over a large portion of the Indian peninsula.

The Transit Instruments, Clocks, and Galvanic apparatus, are intended for the determination of longitudes by Electric Telegraph. Major Walker expressly points to the possibility, at no distant date, when certain telegraphic lines now in progress are completed, of ascertaining the absolute difference of Longitude between Greenwich and Kurrachee in Scinde, and thence the true Longitude of every point in India fixed by the Great Triangulation. And he justly observes that "the importance of such a desideratum can scarcely be over-estimated, not only to Science, but also to Navigation, in furnishing the most accurate basis possible for Maritime Charts." This step having been gained, we cannot pause until the Eastern Archipelago, China, and the Australian Colonies, by being linked in the chain, shall cease to present those dangers to seamen which are incident to uncertainty in the longitude.

I may add the hope that the same method will be employed to render available as a geodesic datum the Arc of Parallel*

* This Arc is designated "*The Great Longitudinal Series, Western Section.*" It was commenced in the season 1848–49, and completed 1852–53. The first eighty miles (at the eastern extremity) was executed by Major

lying between Seronj, in Central India, and Kurrachee, in Scinde, comprising about 10½ degrees of longitude, the triangulation of which was executed with the same high class of instrument, and according to the same rigorous system with which Sir George Everest's Great Meridional Arc was measured. It is verified by a Base-line at either extremity, as well as by frequent astronomical determinations of the Azimuth along its course. The character of this work, and its comparative proximity to the Equator (N. latitude about 25°), will constitute it, when completed by the telegraphic observation of the difference of longitude of its extremities and of various points in its length, a valuable accession to the existing meagre array of Arcs of Parallel of the first order.

It is to be regretted that though a chain of triangles connects Seronj in Central India, and Calcutta, and is therefore nominally a continuation of the Arc of Parallel just referred to, this Eastern section cannot properly be combined with the Western for geodesic purposes. In speaking of this work, Sir Andrew Waugh, whilst giving Mr. Olliver, by whom it was executed, full credit "for his indefatigable exertions under difficult circumstances," adds that, "on account of the defective state of instrumental equipments, the professional value of the work is only of a secondary or tertiary order."* The work was carried on during the absence in Europe of Sir George Everest, then Surveyor-General, prior to the introduction of his admirably organised system, and in days when the supply of superior instruments was not so readily conceded as it since has been. In order to place the Eastern on a par with the Western section, the entire triangulation of the former must be executed *de novo* in the modern style and with appropriate apparatus. The line crosses an insalubrious and difficult tract, it is true, but no work of this kind is free from great obstacles. It is to be hoped that, as the terminal Base-lines at Calcutta and Seronj respectively, which constitute so important and costly a branch of such undertakings, are already measured, and as the Western section is complete, the revision of the Eastern section may eventually be justified by the consideration that the two sections combined will confer on mathematical science a contribution so magnificent as that of a continuous Arc of Parallel of the first order, 21 degrees in length.

London, 13th May, 1862.

Renny Tailyour, Bengal Engineers, and the rest by me. This work constitutes, perhaps, the first example of a true Desert being successfully traversed by a great triangulation.

* Return to the House of Commons, Trigonometrical Survey, India, 15th April, 1851, pp. 5, 6.

Transit of Titan's Shadow across the Disk of Saturn, on 15th April, 1862. By the Rev. W. R. Dawes.

The sixth satellite of *Saturn* (*Titan*) passed its inferior conjunction with the planet on the night of April 15th, and soon afterwards the shadow of the same satellite transited the disk of *Saturn*.

At $10^h\ 31^m$ G.M.T. *Titan* was judged to be at its nearest approach to the planet's north pole. The air was not in a sufficiently good state to render of any use a higher power than 300 on my $8\frac{1}{4}$-inch refractor. With this, the best views showed the satellite quite round, and in loose contact with the disk; but conveying the impression that if the air had been perfectly pure and quiet, a very slight separation might perhaps have been discerned.

Soon after 11^h (time not precisely noted), a shallow circular notch was cut out on the eastern edge of the disk, about one second or a second and a half to the north of the edge of the ring at that place.

At $11^h\ 8^m$, the shadow was judged to have entered one-half its own diameter, the semicircular notch appearing of very considerable size.

At $11^h\ 14^m$, the internal contact was noted; and, in less than half a minute afterwards, the edge of the planet's disk was perceived as a most delicate line of light. The state of the air had improved at this time, and definition with the power then in use (296) was frequently very sharp and steady.

Soon after this, I applied the parallel-wire micrometer, intending to measure the distance between the courses described by the satellite and its shadow, in the direction perpendicular to the axis-major of the ring; but inadvertently the webs were set parallel to the *Earth's* equator instead of *Saturn's*. The mean of six very good measures (with power 286) gave this distance (or *difference of declination*) $= 6''\cdot84$. Taking the inclination of the semi-axis-minor of the ring to the circle of declination at $5°\ 12'$, as given in the Table on page 485 of the *Nautical Almanac* for the present year, this difference of declination becomes $7''\cdot83$, as measured in the direction *perpendicular* to the axis-major of the ring.

The mean of twelve measures of the *difference of right ascension* of the satellite and its shadow, gave $11''\cdot24$; which, reduced in a similar manner, becomes $10''\cdot58$ for the distance in the direction *parallel* to the axis-major of the ring.

The shadow passed along the southern edge of the northern equatoreal belt, encroaching on the belt by nearly one-third of its own diameter.

At $13^h\ 46^m$, the shadow was judged to be precisely in the middle of the chord it described; and this was tested by the webs of the micrometer, which had been previously separated

to a distance equal to the equatoreal semi-diameter of *Saturn;* and each web being placed alternately on the shadow by the quick slipping-piece attached to the driving cylinder, the webs were found to measure equally well both the eastern and western side of the disk.

After the shadow had passed the middle of its transit, I took eight measures of the distance between the satellite and its shadow in the direction parallel to the axis-major of the ring, the mean of which was $10''\cdot89$. But the state of the air had by this time greatly deteriorated, and the planet was between four and five hours west of the meridian. I therefore prefer the result of the calculation given above, namely, $10''\cdot58$.

On the 2d of November, 1789, a similar phenomenon was observed by Sir W. Herschel. He gives the time when he "discovered a black spot on the following margin of the disk of the planet." But this might probably be some minutes after the centre of the shadow coincided with the edge of the disk. Sir William gives $2^h\ 8^m\ 51^s$ as the time which elapsed between his discovery of the spot and its attaining a central position on the disk. The interval between the bisection of the shadow by the limb and its central situation in my observation was $2^h\ 38^m$. The part of the disk transited was nearly the same on both occasions.

I am not acquainted with any other observations of this interesting phenomenon. In the years 1848 and 1849, when the Sun was nearly in the plane of the ring, I looked out diligently for the transits of *Titan* and its shadow; but either from clouds, or the transit occurring in daylight or when the planet was below the horizon, I was never able to observe it; nor have I heard of any other observer who was more fortunate. During the present apparition of the planet also, I have, until the recent occasion, in vain watched for the occurrence of the phenomenon. It will occur again on May 1st and 17th; but I believe that on both those occasions the shadow will be hidden from our view by the interposition of the ring. On the 1st, the path of the shadow will lie within $1''$ to the north of *Saturn's* equator; and on the 17th it will fall on the ring itself, which, from its extremely feeble illumination, will appear as a very dark line across the planet; and it seems exceedingly doubtful whether the shadow, notwithstanding its intense blackness, will be at all discernible upon it.

The *size* of the shadow, however, is far greater than I was prepared to expect. I carefully estimated it at little less than $1''$ in diameter — certainly not less than $0''\cdot8$. It may reasonably be concluded from this that some part of the surface of the satellite is not very reflective; and that, with a large amount of optical power, it might perhaps be perceived as a *dark spot* on the disk of the planet (as is *always* the case with the third and fourth satellites of *Jupiter*), especially if

it should happen in its transit to be projected on the bright equatoreal region. This, however, will not occur during the present season; for though, on August 5th, *Titan* will transit the northern portion of that region, yet it will occur while daylight is so strong as to render it utterly improbable that the satellite could be seen on the disk at all, and very unlikely that even its shadow should be detected.

The third transit of the shadow from the present time will occur on the evening of June 2d; and as it will then fall on the *south* side of the ring, it may probably be seen passing along the southern edge of the extremely narrow *shadow of the ring;* and as its ingress will not take place till about fifty minutes after sunset, and the planet will be only about $2\frac{1}{2}$ hours west of the meridian, it is hoped that the phenomenon will be extensively observed, if the sky should be clear.

The following will be approximately the times of the ingress of *Titan's* shadow for the next seven transits; but the strong daylight and the planet's distance from the meridian will combine to render the last two or three of them very difficult to observe, if not absolutely invisible.

Approximate G.M.T. of Ingress of the Shadow of *Titan*.

		h	m
1862,	May 1, at	10	24
	17,	9	41
	June 2,	8	57
	18,	8	14
	July 4,	7	30
	20,	6	47
	Aug. 5,	6	3

From the great size of the shadow, I believe that the ordinary aperture of a 5-foot refractor ($3\frac{3}{4}$ to 4 inches) would suffice to show it under favourable circumstances of atmospheric purity and altitude of the planet, provided the defining power of the instrument is extremely good.

Hopefield Observatory, Haddenham, near Thame,
1862, *April* 28.

Transit of Titan's Shadow over the Disk of Saturn, on 1st May, 1862. By the Rev. W. R. Dawes.

Clouds most unfortunately prevented the observation of the transit of the shadow of *Titan* over the disk of *Saturn* on the night of May 1st. A glimpse showed the satellite near its inferior conjunction at $8^h\ 15^m$; but after that the planet re-

mained invisible; and, consequently, I have no means of applying, as I hoped to do, any correction from observation to the calculated time given at the conclusion of my former paper.

Hopefield Observatory, 1862, *May* 3.

In a letter to the Editor, dated 26th May, Mr. Dawes writes that on the 17th he made a capital observation of the transit of *Titan's* shadow; and that on the 25th he watched an *immersion* of that satellite into the *shadow* of *Saturn*.

Transit of Mercury of 11*th November*, 1861.

(*Extract of a Letter from Charles Todd, Esq., Observatory and Telegraph Department, Adelaide, to the Astronomer Royal, dated* 1861, *Nov.* 26.)

I had a glorious day for observing the transit of *Mercury* on the 12th instant (11th G. T.), with a Dollond of $2\frac{1}{4}^{\text{in}}$ aperture.

	h m s
Total Ingress	2 34 12 A.M.T., very exact.
Egress, int. cont.	6 30 29 A.M.T., rather doubtful; Sun low.
Total Egress	6 32 19 A.M.T., very doubtful; limb boiling; Sun near setting.

Some very fine large clusters of spots on the Sun.

Observations of Comet II. 1861, *made with the Northumberland Equatoreal at the Cambridge Observatory.* By J. C. Adams, Esq., Director of the Observatory.

	G.M.S.T. 1861.	Observed R.A.	Parallax × Δ	Observed N.P.D.	Parallax × Δ
d	h m s	h m s		° ′ ″	
June 30	11 6 7·4	6 40 14·94	+0·127	43 25 37·1	−8·343
	11 19 51·1	6 40 40·50	+0·099	43 19 35·0	−8·391
July 2	10 41 46·6	8 30 28·47	+0·541	...	...
	10 57 47·4	..	..	27 36 40·5	−6·571
3	9 57 55·6	9 39 53·92	+0·822	24 10 11·5	−4·128
	11 4 52·4	9 43 15·42	+0·726	24 4 38·6	−5·330
5	10 29 33·1	11 44 52·88	+0·868	23 38 32·8	−2·301
8	9 54 51·8	13 17 34·82	+0·624	27 54 50·1	−0·573
	10 53 7·9	13 18 22·15	+0·706	27 58 30·1	−1·627
9	11 4 31·9	13 35 4·31	+0·673	29 23 45·7	−1·767
	11 56 10·5	13 35 36·11	+0·709	29 26 47·9	−2·768
10	11 7 1·7	13 47 55·32	+0·641	30 40 45·8	−1·800
13	11 22 27·6	14 13 11·05	+0·588	33 47 49·3	−2·208

	G.M.S.T. 1861.	Observed R.A.	Parallax × Δ.	Observed N.P.D.	Parallax × Δ.
d	h m s	h m s		° ′ ″	
July 23	10 32 49·0	14 46 40·09	+0·469	39 26 26·8	−2·151
26	10 32 17·3	14 51 52·27	+0·466	40 27 2·2	−2·369
27	10 33 40·2	14 53 23·97	+0·469	40 44 52·1	−2·456
31	10 26 32·3	14 58 53·10	+0·462	41 47 58·5	−2·630
Aug. 1	10 35 45·8	15 0 8·70	+0·473	42 2 10·6	−2·835
2	10 32 1·3	15 1 21·77	+0·469	42 15 28·0	−2·850
6	10 6 13·3	15 5 58·48	+0·448	43 3 51·5	−2·718
8	11 36 5·3	15 8 15·87	+0·508	43 26 28·1	−4·273
13	10 50 16·2	15 13 38·37	+0·489	44 14 56·1	−3·837
14	10 5 46·4	15 14 40·53	+0·459	44 23 31·9	−3·202
15	10 17 49·8	15 15 45·60	+0·470	44 32 18·2	−3·444
16	10 9 30·0	15 16 49·44	+0·404	44 40 41·4	−3·375
19	10 29 28·4	15 20 3·57	+0·480	45 4 48·1	−3·860
20	10 17 53·8	15 21 7·81	+0·474	45 12 18·1	−3·735
21	9 22 2·6	15 22 10·59	+0·429	45 19 26·2	−2·960
23	9 45 40·3	15 24 22·39	+0·454	45 33 50·1	−3·414
24	9 31 49·0	15 25 27·54	+0·443	45 40 36·9	−3·265
27	10 12 6·3	15 28 50·08	+0·475	46 0 31·3	−4·034
28	10 12 2·4	15 29 57·85	+0·476	46 6 45·7	−4·088
30	9 22 4·7	15 32 10·76	+0·445	46 18 33·4	−3·437
Sept. 3	9 57 56·4	15 36 50·93	+0·472	46 40 58·0	−4·183
6	8 47 24·9	15 40 21·31	+0·427	46 55 58·1	−3·285
7	9 17 36·4	15 41 35·06	+0·453	47 0 49·0	−3·770
9	8 45 16·6	15 43 59·40	+0·431	47 10 1·5	−3·394
10	9 44 31·5	15 45 16·09	+0·470	47 14 35·8	−4·323
11	9 19 54·9	15 46 29·07	+0·460	47 18 47·9	−3·996
12	10 24 59·8	15 47 46·77	+0·477	47 23 9·1	−5·047
13	10 37 13·6	15 49 3·41	+0·475	47 27 11·9	−5·284
14	9 45 6·2	15 50 16·27	+0·472	47 30 53·2	−4·521
23	10 12 4·0	16 2 1·87	+0·470	47 59 51·8	−5·342
Oct. 9	9 30 36·3	16 24 25·11	+0·467	48 25 8·7	−5·358
11	8 57 45·5	16 27 20·63	+0·468	48 25 45·7	−4·935
12	10 38 55·7	16 28 56·26	+0·429	48 25 51·1	−3·473
14	9 55 27·1	16 31 52·46	+0·452	48 26 0·1	−5·918
15	9 14 45·4	16 33 20·43	+0·466	48 25 40·7	−5·342
16	8 32 50·6	16 34 47·90	+0·467	48 25 22·8	−4·740
23	8 21 25·1	16 45 33·56	+0·469	48 18 53·2	−4·813
28	7 35 56·1	16 53 23·50	+0·460	48 10 7·4	−4·290
Nov. 1	7 36 39·0	16 59 49·13	+0·465	48 0 34·7	−4·426
2	8 57 36·6	17 1 31·62	+0·464	47 57 36·8	−5·698
	9 1 53·1	17 1 32·41	+0·462	47 57 37·9	−5·761
5	8 3 14·1	17 6 21·53	+0·473	47 48 43·1	−4·959
6	7 52 51·5	17 7 59·25	+0·473	47 45 28·2	−4·830

	G.M.S.T. 1861.	Observed R.A.	Parallax × Δ.	Observed N.P.D.	Parallax × Δ.
d	h m s	h m s		° ′ ″	
Nov. 7	8 2 21·5	17 9 38·79	+0·474	47 41 56·1	−5·008
9	8 43 42·4	17 13 1·20	+0·466	47 34 15·6	−5·721
11	8 38 55·1	17 16 20·95	+0·465	47 26 31·6	−5·689
20	6 53 55·6	17 31 30·01	+0·476	46 43 49·4	−4·315
23	7 49 1·8	17 36 44·66	+0·482	46 26 28·5	−5·327
27	6 55 5·0	17 43 39·16	+0·485	46 2 18·8	−4·507
28	6 56 14·3	17 45 24·37	+0·486	45 55 48·9	−4·554
30	7 58 3·9	17 48 59·05	+0·479	45 42 56·9	−5·575
Dec. 3	7 27 26·7	17 54 16·40	+0·490	45 21 10·9	−5·193
4	7 55 49·1	17 56 5·36	+0·480	45 13 45·6	−5·653
5	8 7 48·6	17 57 53·10	+0·472	45 6 8·5	−5·882

The foregoing values were deduced as follows:—

	R.A. Comet — Star.	No. of Comp.	N.P.D. Comet — Star.	No. of Comp.	Star.
d	m s		′ ″		
June 30	− 6 1·85	1	− 7 37·2	1	*a*
	−11 50·63	1	−31 27·0	1	*b*
July 2	{−11 26·54 {− 8 10·07	3	..	..	{*c* {*d*
			{+ 5 23·9 {− 2 54·2	2	{*c* {*d*
3	−28 2·06	1	− 1 49·4	1	*e*
	+ 3 46·57	3	+18 55·2	3	*f*
5	− 4 25·66	6	−20 23·8	6	*g*
8	−27 41·47	1	+ 5 53·8	1	*h*
	+ 3 2·19	5	+ 6 13·7	5	*i*
9	−29 25·99	1	−36 22·5	1	*k*
	− 3 33·03	2	+17 31·6	2	*l*
10	+ 2 11·99	6	− 5 28·7	6	*m*
13	− 6 13·30	4	+ 0 24·9	4	*n*
23	− 5 8·51	4	−21 37·8	4	*o*
26	− 5 2·31	7	+11 44·6	7	*p*
27	+ 5 42·19	4	− 0 32·1	4	*q*
31	− 0 21·65	11	− 0 9·5	11	*r*
Aug. 1	+ 0 53·98	6	+14 2·6	6	*r*
2	+ 5 25·25	6	+ 5 11·4	6	*s*
6	+ 1 54·96	8	+ 4 32·4	8	*t*
8	− 5 18·81	3	−25 49·5	3	*u*
13	− 5 47·78	6	+ 0 51·3	6	*v*
14	− 4 45·59	2	+ 9 27·1	2	*v*
15	+ 1 48·85	8	+ 3 47·8	8	*w*
16	+ 2 52·72	6	+12 10·9	6	*w*
19	− 1 12·06	8	− 7 43·3	8	*x*

	R.A. Comet—Star.	No. of Comp.	N.P.D. Comet—Star.	No. of Comp.	Star.
d	m s		′ ″		
Aug. 20	+ 0 59·93	8	+ 3 45·8	8	*y*
21	+ 0 55·02	8	+ 6 54·8	8	*x*
23	+ 2 42·01	8	+ 3 30·7	8	*z*
24	+ 3 47·18	8	+10 17·3	8	*z*
27	− 4 51·96	6	+ 4 7·9	6	*a a*
28	− 3 44·16	6	+10 22·2	6	*a a*
30	+ 1 44·81	8	− 3 36·4	8	*b b*
Sept. 3	+ 2 3·92	6	−10 3·6	6	*c c*
6	− 1 9·31	6	− 9 53·5	6	*d d*
7	− 4 41·08	6	− 0 3·6	6	*e e*
9	− 2 16·69	6	+ 9 8·7	6	*e e*
10	− 2 37·66	6	+ 5 12·8	6	*f f*
11	− 1 24·66	6	+ 9 24·8	6	*f f*
12	− 0 6·93	8	+13 45·9	8	*f f*
13	+ 1 9·73	6	+17 48·5	6	*f f*
14	+ 2 22·62	6	+21 29·7	6	*f f*
23	− 2 36·92	4	−32 34·3	4	*g g*
Oct. 9	+ 1 46·87	8	− 1 15·5	8	*h h*
11	− 4 43·97	6	+ 6 7·8	6	*i i*
12	− 3 8·32	2	+ 6 13·0	2	*i i*
14	− 5 44·14	4	− 6 20·8	5	*k k*
15	− 4 16·15	6	− 6 40·4	6	*k k*
16	− 2 48·66	8	− 6 58·4	8	*k k*
23	+ 1 0·70	6	+13 15·6	6	*l l*
28	− 2 20·76	8	−10 55·2	8	*m m*
Nov. 1	+ 0 57·26	8	+ 6 18·9	8	*n n*
2	− 0 34·14	7	− 0 6·2	7	*o o*
	+ 2 40·55	2	+ 3 21·9	2	*n n*
5	− 2 47·38	8	+ 4 58·1	8	*p p*
6	− 1 9·64	7	+ 1 42·9	7	*p p*
7	+ 0 29·91	9	− 1 49·5	9	*p p*
9	+ 2 39·71	4	− 3 46·3	3	*q q*
11	− 0 48·10	9	− 9 12·8	9	*r r*
20	+ 1 1·34	8	+13 17·5	8	*s s*
23	+ 0 19·00	6	− 0 59·9	5	*t t*
27	− 0 15·83	8	+11 34·8	6	*u u*
28	+ 1 29·36	8	+ 5 4·7	6	*u u*
30	− 0 51·62	8	− 5 34·2	6	*v v*
Dec. 3	− 1 9·17	8	+ 4 43·9	6	*w w*
4	+ 0 39·79	8	− 2 41·7	6	*w w*
5	+ 2 27·53	8	−10 19·1	6	*w w*

The determinations of N.P.D. from July 2 to July 9, inclusive, are liable to some uncertainty, in consequence of the defective state of the clamp by

which the declination-rod was attached to the polar frame. The determinations of R.A., however, are trustworthy.

The R.A. and N.P.D. for July 2 are obtained by taking a mean between the results of the comparisons with (*c*) and (*d*).

It is probable that in the observation of Nov. 30 the recorded micrometer-reading was too great by 5 revolutions, and that the N.P.D. should consequently be diminished by $5^r = 43''\cdot 2$.

Assumed Mean Places of the Stars of Comparison for 1861·0.

Star.	R.A. 1861·0. h m s	N.P.D. 1861·0. ° ′ ″	Authority.	
a	6 46 15·02	43 33 14·32	Johnson	1841
b	6 52 29·36	43 51 2·00	Arg.	7473
c	8 41 53·41	27 31 18·42	Johnson	2212
d	8 38 36·47	27 39 33·30	Arg.	9299
e	10 7 54·05	24 12 1·81	Johnson	2464
f	9 39 26·98	23 45 44·11	,,	2396
g	11 49 16·42	23 58 58·28	Arg.	12183–84
h	13 45 13·86	27 48 58·73	Johnson	3103
i	13 15 17·63	27 52 18·45	Arg.	13563
k	14 4 27·81	30 0 10·61	Johnson	3147
l	13 39 6·75	29 9 18·43	,,	3084
m	13 45 40·92	30 46 16·61	,,	3104
n	14 19 21·88	33 47 26·83	Arg.	14545
o	14 51 46·18	39 48 7·45	Johnson	3293
p	14 56 52·21	40 15 20·75	Arg.	15039
q	14 47 39·45	40 45 27·01	,,	14924–5 and 6
r	14 59 12·46	41 48 11·30	Johnson	3318
s	14 55 54·28	42 10 19·81	,,	3306
t	15 4 1·33	42 59 22·55	Arg.	15138, 39 & 4
u	15 13 32·48	43 52 21·45	,,	15266
v	15 19 24·05	44 14 8·99	,,	15347
w	15 13 54·71	44 28 34·20	,,	15272
x	15 21 13·64	45 12 35·38	Johnson	3385
y	15 20 5·93	45 8 36·32	Arg.	15355
z	15 21 38·49	45 30 23·41	Johnson	3387
a a	15 33 40·19	45 56 27·99	,,	3423
b b	15 30 24·17	46 22 13·89	,,	3413
c c	15 34 45·30	46 51 5·65	,,	3431
d d	15 41 28·95	47 5 56·02	,,	3448
e e	15 46 14·48	47 0 57·43	,,	3462
f f	15 47 52·16	47 9 27·67	,,	3464
g g	16 4 37·39	48 32 30·79	H. C.	29530
h h	16 22 37·14	48 26 28·41	,,	30042
i i	16 32 3·53	48 19 43·04	Eq. Comparison.	
k k	16 37 35·56	48 32 26·10	H. C.	30489
l l	16 44 32·00	48 5 41·91	,,	30687

Star.	R.A. 1861·0. h m s	N.P.D. 1861·0. ° ′ ″	Authority.
m m	16 55 43·43	48 21 7·36	H. C. 31031
n n	16 58 51·13	47 54 20·14	B. Z. 426. $16^h 57^m 41^s$
o o	17 2 5·02	47 57 47·50	Eq. Comparison.
p p	17 9 8·21	47 43 49·86	H. C. 31417
q q	17 10 20·85	47 38 5·93	,, 31456
r r	17 17 8·42	47 35 49·01	,, 31697
s s	17 30 28·18	46 30 36·13	,, 32154 and 5
t t	17 36 25·19	46 27 32·75	Johnson 3741
u u	17 43 54·58	45 50 48·38	,, 3763
v v	17 49 50·27	45 48 35·65	B. Z. 478. $17^h 47^m 53^s$
w w	17 55 25·32	45 16 31·59	Eq. Comparison.

The place assumed for the star (*i i*) is derived from equatorial comparisons made on Oct. 15 with H. C. 30489. The place of (*o o*) is derived from equatorial comparisons made on Nov. 20 with B. Z. 426. $16^d 57^m 41^s$, and the place of (*w w*) from equatorial comparisons with Johnson 3795 made on Feb. 20, 1862.

The observations up to July 13 were made by Professor Challis, and the subsequent ones by Mr. Bowden, the senior Assistant at this Observatory.

Cambridge Observatory,
April 25th, 1862.

Observations of Encke's Comet. By W. Scott, Astronomer for New South Wales.

(*Extract of a Letter to the Astronomer Royal, dated Observatory, Sydney, March* 22, 1862.)

"I send you herewith the only good observations I have been enabled to obtain of Encke's Comet. The weather has been cloudy or hazy for the last two months, and the Comet was, at the best, very indistinct and ill defined.

Observations of Encke's Comet with the 7-inch Equatoreal and Ring-Micrometer.

Greenwich M.T. d h m s	R.A. Comet − Star. m s	Decl. Comet − Star. ′ ″	Star.
Feb. 23 5 45 14	−5 37·7	+4 25	*a*
53 24	−1 37·8	−0 3	*b*
6 1 36	−1 36·3	−0 13	*b*
7 6	−1 35·7	+0 7	*b*
11 31	−1 36·0	+0 3	*b*
11 31	−5 35·1	+4 5	*a*

Stars of Comparison; *a*, B.A.C. 7216; *b*, 8th mag. R.A. $20^h 38^m 22^s$; Decl. $-25° 25'$.

Greenwich M.T.		R.A. Comet—Star.	Decl. Comet—Star.	Star.
	d h m s	m s	′ ″	
Feb. 24	5 43 26	−3 27·6	+5 24	*a*
	49 14	−3 27·2	+5 17	*a*
	56 6	−3 26·8	+5 29	*a*
	6 3 6	+0 33·8	+0 58	*b*
	9 40	+0 34·3	+1 2	*b*
	12 2	+0 34·2	+0 53	*b*

Stars of Comparison same as before.

Results of Meridional Observations of Small Planets; Occultation of a Star by the Moon; and Phenomena of Jupiter's Satellites; observed at the Royal Observatory, Greenwich, during the month of April, 1862.

(*Communicated by the Astronomer Royal.*)

Flora (8).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, April 3	13 14 50·6	14 3 15·27	92 22 40·99
15	12 16 16·5	13 51 50·22	91 11 5·40
17	12 6 25·2	13 49 50·40	91 0 4·04
21	11 46 42·2	13 45 50·39	90 39 16·90
22	11 41 46·9	13 44 50·87	90 34 27·76
24	11 31 57·4	13 42 52·80	90 25 6·09
26	11 22 9·5	13 40 56·38	90 16 17·62
28	11 12 23·8	13 39 2·26	90 8 8·48
30	11 2 41·1	13 37 11·04	90 0 35·02

Melpomene (18).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, April 22	13 11 57·5	15 15 16·28	92 28 42·64
29	12 38 18·2	15 9 7·30	91 43 32·50

Fortuna (19).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, April 17	9 55 53·5	11 38 57·33	88 47 7·61
21	9 38 10·4	11 36 57·47	88 31 21·76

Thalia (23).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, April 3	9 32 13·4	10 20 1·57	62 11 46·71

Euterpe (27).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, April 3	12 49 26·1	13 37 46·66	97 26 2·94
17	11 40 56·1	13 24 17·12	96 9 42·67
21	11 21 29·1	13 20 33·19	95 49 26·26
24	11 7 0·5	13 17 51·80	95 35 0·59
25	11 2 12·6	13 16 59·70	95 30 24·92
28	10 47 55·0	13 14 29·45	95 17 23·52
29	10 43 11·2	13 13 41·41	95 13 15·87

Amphitrite (29).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, April 17	9 45 9·8	11 28 11·83	87 59 18·66
21	9 27 35·5	11 26 20·37	87 54 55·24
23	9 18 57·3	11 25 34·38	87 53 30·20
28	8 57 48·1	11 24 4·40	87 52 13·47
29	8 53 38·8	11 23 51·06	87 52 26·30

All the observations of N.P.D. have been corrected for refraction and parallax.

The reappearance of B.A.C. 4923, on 1862, April 15, at the Moon's bright limb was observed by Mr. Criswick to take place at $13^h\ 50^m\ 34^s{\cdot}7$ G.M.T.

Phenomena of Jupiter's Satellites.

Day of Observation.	Satellite.	Phenomenon.	Mean Solar Time.	Observer.
1862.			h m s	
April 15	I	Egress, bisection	13 58 48·6	C.
15	I	„ last cont.	14 0 18·3	C.
17	I	„ bisection	8 25 25·1	J. C.
22	I	Ingress, bisection	13 29 58·8	E.
24	I	Egress, bisection	10 12 7·9	D.
24	I	„ last cont.	10 15 7·4	D.
25	I	Eclipse, reapp.	8 17 55·3	J. C.
25	II	Eclipse, reapp.	11 11 55·0	J. C.

The initials D., E., C., and J. C., are respectively those of Mr. Dunkin, Mr. Ellis, Mr. Criswick, and Mr. Carpenter.

Ephemeris of Proserpine (26). By M. Hoek, Director of the Observatory of Utrecht.

(*Letter to the Astronomer Royal, dated Utrecht*, 1862, *May* 20.)

"J'ai l'honneur de vous adresser une éphéméride pour l'opposition prochaine de *Proserpine* (26), éphéméride qui a été déduite par interpolation, du Jahres-éphéméride dans le *Berliner Astronomisches Jahrbuch für* 1864, et qui a déjà été corrigée (d'après l'indication de M. Kam à Leÿde) par -3^s en R.A., et $0'\cdot0$ en Decl.

"Monsieur Kam a eu la complaisance de chercher la planète, de sorte que vous la trouverez aux endroits suivantes:—

T.M. de Berlin. 1862.	R.A. h m s	Decl. ° ′	Log Δ.	Temps de Transmission de la Lumière. m s
Mai 25·5	17 29 32	−26 15·3	0·1628	11 57·5
26·5	28 42	16·6	·1618	55·7
27·5	27 50	17·8	·1608	54·0
28·5	26 58	19·0	·1598	52·4
29·5	26 4	20·2	·1589	51·0
30·5	25 9	21·4	·1581	49·7
31·5	24 13	22·5	·1573	48·5
Juin 1·5	23 17	23·5	·1567	47·4
2·5	22 20	24·5	·1561	46·5
3·5	21 23	25·3	·1556	45·7
4·5	20 25	26·1	·1552	45·0
5·5	19 27	26·9	·1548	44·5
6·5	18 28	27·5	·1546	44·1
7·5	17 29	28·1	·1544	43·8
8·5	16 29	28·7	·1543	43·6
9·5	15 29	29·2	·1543	43·5
10·5	14 29	29·6	·1543	43·5
11·5	13 29	30·0	·1545	43·7
12·5	12 29	30·3	·1547	44·0
13·5	11 30	30·5	·1549	44·5
14·5	10 31	30·6	·1553	45·2
15·5	9 33	30·7	·1557	46·0
16·5	8 35	30·7	·1563	46·9
17·5	7 37	30·7	·1569	47·9
18·5	6 40	30·7	·1575	49·0
19·5	5 44	30·6	·1583	50·1
20·5	4 48	30·4	·1591	51·4
21·5	3 53	30·2	·1600	52·8
22·5	2 59	29·9	·1610	54·4
23·5	2 5	29·5	·1620	56·2
24·5	17 1 12	−26 29·1	0·1632	11 58·2

" Si vous vouliez communiquer cette éphéméride aux astronomès Anglais qui pourraient s'y intéresser, vous m'obligeriez fort."

Further Note on the supposed Observation of an Intra-Mercurial Planet on the 12th of February, 1820.

Mr. Carrington has been favoured with the following letter from Dr. von Littrow, which he hastens to communicate a translation of, referring at the same time to the *Monthly Notices*, vol. xx. p. 194.

" *Vienna, April 13th, 1862.*

"A fortunate chance has, at length, led me to-day to a source whence I have obtained further information respecting the observation of Steinheibel.

"In the Vienna *Times* of April 27th, 1820, there is to be found the following notice, communicated probably by my father:—

" 'Mr. Steinheibel, who for the last four years has daily observed the Sun and recorded his spots and faculæ with care in a diary, on February 12th (1820), at $10^h 45^m$ in the morning, observed a spot, which was distinguished from all the rest by its well-defined circular form, by its equally circular atmosphere, by its orange-red colour, and especially by its unusual motion, completing the diameter of the Sun in nearly five hours. As he made this interesting observation during a country excursion, it was impossible to have recourse to instruments or to communicate the phenomenon early enough to others; yet he is ready to answer fully every question put to him about this occurrence. It is very possible that a planet might be discovered in this way, having its orbit within that of *Mercury*; and should the zeal with which Mr. Steinheibel has pursued this class of observations for a series of years, be rewarded by such a happy result, and lead him to publish his observations on the Sun, they would not be without interest for the public.'

"I have in a former letter incorrectly written the name 'Steinheibel,' according to Olbers, 'Steinhübel.' He lived for some time as Abbé at Vienna, and subsequently at Kremsmünster; at both of which places he occupied himself continuously with observations of the Sun. The above observation of his is given so differently to that of Starke, that I should consider it independent of the latter."

Mr. Lassell writes to correct an error (p. 164 of the *Monthly Notices*), where it is stated that the new star discovered by him within the trapezium of the great nebula of

Orion "appears to be about a full magnitude less than that known as 'the sixth star;' and is about one-sixteenth of its distance from *Theta*." Mr. Lassell's note at the time in his journal states "about five-eighths of the distance of the sixth star from *Theta*." On referring to his original communication, it appears that the distance there mentioned was *six-tenths*, which was inadvertently printed as *one-sixteenth*.

On the Missing Nebula in Coma Berenices. By M. Chacornac.

(*Extract of a Letter to Sir J. Herschel, dated Paris, 22d May*, 1862.)

"Permettez moi de vous adresser quelques renseignements sur la nébuleuse variable dont vous annoncez la disparition dans le No. 6 du xxii^{me} volume des *Monthly Notice*.

"Le 19 Avril dernier, ayant dirigé le grand téléscope de M. Foucault sur la région du ciel environnant l'étoile (6) de la constellation de la chevelure de *Bérénice*, dans le but d'étudier la structure des nébuleuses qui s'y trouvent condensées; j'y remarquai une nébuleuse double dont l'une des deux composantes avait un éclat bien plus faible que l'autre, ce qu'il était facile d'apprécier par leur visibilité dans le même champ de vue.

"En dirigeant de nouveau le même instrument sur le lieu que vous désignez, j'ai reconnu que les trois nébuleuses cataloguées se trouvent à peu près à leur place respective que vous indiquez. Les deux objets (A) et (B) sont bien de première classe et une étoile de dixième à onzième grandeur précède bien la nébuleuse (B) de 24^s, mais je trouverais une différence d'ascension droite moins grande entre ces deux objets, c'est à dire:—

$$\text{R.A. (B)} - \text{R.A. (A)} = 13^{s}\cdot 5.$$

"La troisième nébuleuse peu éloignée de (B) est bien celle que j'ai aperçue le 19 Avril; elle répond assez bien aux différences que vous annoncez mais elle brille d'un faible éclat. Sa constitution analogue à celle de (B) m'a permis de comparer son intensité lumineuse à celle de cette nébuleuse au moyen d'un micromètre à double image appliqué au téléscope; j'ai trouvé ainsi la lumière du compagnon quatre fois plus faible que celle de la nébuleuse principale (B)."

Mr. Rümker has presented to the Society the manuscripts containing his Observations of Southern Stars made at Paramatta in the years 1826 and 1827. The thanks of the Council were voted to him for this valuable gift.

On Heliotypography. By Warren De La Rue, Esq.

The accompanying print of Sun-spots was produced from a collodion negative, taken by means of my Newtonian reflector of 18 inches aperture and 10 feet focal length, on the scale of 3 feet for the Sun's diameter.

The original focal image was enlarged before reaching the sensitive plate from about 1 inch in diameter to the scale of the picture, by means of a new combination of lenses which projects the image without sensible distortion on a flat field, and whose visual and chemical foci coincide perfectly.

The camera which is attached to the eye-end of the telescope will hold a plate 18 × 18 inches, so that about one-fourth of the Sun can be depicted at one time. Even for a picture of such a size, the apparatus is very heavy, and could not be carried safely at one end of the tube, unless a provision had been made to support it. This is effected by means of a radius bar, which moves on a short independent axis, fixed on the framing of the telescope, in the prolongation of the polar axis.

When Sun-pictures are taken, the telescope tube is for convenience rotated in its cradle through an arc of 90° from its ordinary position, so as to place the eye-piece underneath. To the sliding tube which carries usually the eye-piece, is fixed the instantaneous apparatus, which moves in a direction at right angles across the tube. The moveable plate of the instantaneous apparatus slides as nearly as possible in the plane of the primary focal image.

The enlarged image is received at a distance of about 4 feet from the secondary magnifier.

The printing block was produced by M. Paul Pretsch, according to a method he has invented. The process may be rendered sufficiently clear without revealing the exact process, which he does not wish to disclose at present.

Gelatine is mixed with a salt of chromic acid, such as bi-chromate of potash, and poured on to a glass plate, and allowed to dry in the dark. If a plate so prepared is exposed to light, and a similar plate is retained in the dark, and the two plates are subsequently moistened with water, it will be found that the gelatine which has not been exposed to the

Printed at the ordinary Typographical Press from an Electro-copper Block, obtained from the original Negative by means of Light and Electro-metallurgy.
Absolutely untouched by the Graver.

action of the light will swell up like ordinary gelatine, while that which has been exposed to light will have become changed, and will remain unacted on by the water.

If, therefore, an ordinary negative be placed over the dry prepared film of gelatine, and both are submitted to the action of light, the gelatine will become more or less changed in proportion to the intensity of the light transmitted through the several parts of the negative. For example, in the case of a negative of a Sun-spot, much light will pass through the image of the spot, less through that of the penumbra, and still less through that of the bright parts of the Sun's surface, and the light so transmitted will produce a corresponding hardening of the prepared surface.

When therefore the plate is subsequently moistened, the part corresponding to the spot will remain flat, more or less in proportion to the intensity of light which has acted on it, the bright parts will swell, and the gelatine film will represent the matrix of a surface-printing block.

It is now only necessary to obtain, by means of known processes in electro-metallurgy, a counterpart of the gelatine. The plate so prepared is the printing block, which will furnish many thousand impressions at an ordinary printing-press, it being however necessary from time to time to clear the block, which is liable to become clogged on account of the want of depth in the light parts. On observing the impression at a little distance from the eye, a sort of mottling will be perceived on the bright parts of the picture; this is a true representation of the Sun's surface; on the other hand, an examination of the picture by means of a magnifier will show a vermicelli sort of granulation, which does not belong to the Sun, but results from the process and arises from the change which takes place in the gelatine film passing as it were from the gelatinous or dynamic condition to the crystalline or static condition of matter.

The grain may be made coarser or finer, and need in no way interfere with a picture more than the lines of a steel plate or the grain of a lithographic stone interferes with pictures engraved on the first or drawn on the second.

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Printed by STRANGEWAYS and WALDEN, Castle St. Leicester Sq. and Published at the Apartments of the Society, June 16, 1862.

// MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXII. *June* 13, 1862. No. 8.

Dr. LEE, President, in the Chair.

David Smith, Esq., Birmingham; and
John Robertson, Esq., Glasgow,
were balloted for and duly elected Fellows of the Society.

On the proposed Parallax Observations of Mars in 1862.
By Prof. C. Piazzi Smyth.

In the important paper of Dr. Winnecke, of Pulkova, in the *Bulletin* of the St. Petersburg Academy, entitled, "Considerations concernant les Observations Méridiennes à faire pendant l'Opposition prochaine de *Mars*, dans le but de déterminer sa Parallaxe," that able astronomer sets forth—and, as we may assume, satisfactorily—first, the large amount of uncertainty at present existing in the received value of the Solar Parallax (probably $\frac{1}{30}$th of the whole); secondly, the extreme desirability of improving this determination; and, thirdly, the unusually favourable opportunity which the opposition of *Mars* offers this autumn, beyond and before most of the recent oppositions, for attaining to the desired consummation. He then proceeds to select a series of stars admirably calculated by their position to be compared in declination with *Mars*, each night from August 20th to November 3d, and, finally, to announce that his method of observation will be bisection, or its equivalent, at Meridian transits with a meridian transit-circle.

Now every one knows that whatever may be done at all with a meridian transit-circle will be done by such an instrument at the Central Observatory at Pulkova, with an accuracy which will be an example to almost every country; but yet one may express surprise that in this case a *meridian*-circle should have been chosen; for the object proposed to be immediately gained is, a micrometrical difference only between *Mars* and the stars of comparison, and is therefore more suitable to a large *Equatoreal*, especially as the number of days during which the parallactic effect will be at its maximum is very small, and observations should rather be accumulated at that particular time than thinly spread over many months of smaller parallax.

Of course the intelligent author of the paper referred to has a reason for the opinion he has come to; and it appears to be, firstly, that in so high a northern latitude as Pulkova, measures taken with an Equatoreal "at great distances from the meridian, as recommended by Mr. Airy, would be attended with very grave inconveniences;" and, secondly, that he has not been certified that there will be any observations of any kind made at any Southern Observatory.

With regard to the first of these reasons, I cannot say anything with authority; but with regard to the second, it appears to me a duty to one of the absent Astronomers of the South referred to (viz. Sir Thomas Maclear, at the Cape of Good Hope), to mention, that I had the honour of receiving from him a letter, towards the end of 1860, detailing his observations of the *Mars* opposition of that year, and describing them with such extraordinary enthusiasm, and looking on them as so essentially his bounden duty, that I at least entertain no reasonable doubt but that he will attend to the opposition of 1862 as honestly and as ably. Furthermore, I should mention —though without any official authority so to do, and subject to correction—that Sir Thomas had made all the observations of 1860 with the 6-inch Equatoreal of the Cape Observatory, and expressed himself perfectly delighted with the superior power of that instrument for that purpose (viz. measuring micrometrical distances between *Mars* and certain stars near him) over the meridian instruments which he had been obliged to employ on former occasions; and he stated his belief that one night with the said Equatoreal was about as good as fifteen nights, I think, with the meridian instruments.

Hence there seems not only a chance amounting to all but certainty, that the *Mars* opposition of 1862 will be observed in the chief Southern Observatory, but that it will be observed with an Equatoreal in preference to a meridian instrument; and with this Equatoreal the observations will be made— according to the plan of 1860—not so much at great distances from the Meridian, as on and near the Meridian: a position which, it is hoped, will allow the great Pulkova telescope to

be similarly employed, without any of the very grave inconveniences which had been feared for it.

Here terminates, therefore, the first part of the subject; but then immediately forces itself upon our attention this case, whether, granted that the two established Observatories of the North and South fully perform their local parts, is the desired end likely to be obtained — viz. not only an accurate determination of the parallax of *Mars*, but a something so exceedingly accurate that it shall command the attention and elicit the respect of all other astronomers as well, besides those who have assisted at the observations, and to a degree which shall induce them to alter the parallax of the Sun as deduced from the transit of *Venus* in 1769?

In seeking an answer to this requirement, we are met at once by the unflattering circumstance, that oppositions of *Mars* have been observed again and again of late years, and without any such decided step being gained as would warrant an alteration of the received parallax of $8''\cdot5776$. What, then, can be particularly said of the opposition of 1862, that should lead us to expect much better results from it than from its predecessors? This is a point which has not escaped the acuteness of Dr. Winnecke; and he accordingly mentions — besides previous observations North and South not being very comparable — that the planet itself was not on those occasions at its least terrestrial distance, which it will be very nearly at in 1862, "or only 0·4 from the Earth, the Earth's mean distance from the Sun being 1·0."

In referring to the *Nautical Almanac*, however, it appears that whereas the parallax of *Mars* will be $21''\cdot2$ on Sept. 28th, 1862, it was no less than $21''\cdot9$ on July 20th, 1860; consequently the opposition of that year was more favourable in so far by $\frac{1}{30}$, and constituted, therefore, the season when all the observations concerned should have been working for the parallactic difference, rather than in 1862. The Northern Astronomers were, however, hindered in their part of the scheme by their joining the eclipse expedition to Spain — the eclipse occurring on the 18th July, and the *Mars'* opposition observations extending over June, July, and August. This appears to give some excellent hints; for, if many *Mars* observations were lost on that occasion, it has been allowed on the other hand by all persons, that the eclipse gained immensely by the said expedition; and, in truth, expeditions are not only most powerful means for making the most of any special astronomical phenomenon, but they have never yet had full scope given to them; although their results have been, in almost every case when they have been tried, successful. What for instance, it may be asked, would have been the transit of *Venus* in 1796, but for the numerous geographical expeditions that were fitted out to observe it from special and peculiar points of the earth's surface? To this question

we would hardly answer, "Nothing," but rather, "A something so little accurate, that it would have yielded long since to very ordinary *Mars'* opposition observations."

If, then, the *Venus'* observations were, by astronomical expeditions, rendered so much more powerful for their useful end than they otherwise would have been, why should not the *Mars* observations receive the same auxiliary aid? The weaker astronomical phenomenon (for getting at the Solar parallax) surely needs all the more geographical magnifying of the effect, if its result is to be used in correcting the conclusions of the other. But if this magnifying be not done, then, no matter what result the present fixed Observatories arrive at, they will inevitably *not* be considered by the astronomical world to have settled the parallax of *Mars;* for they so plainly leave an opportunity to some one else, only a couple of years after, to make the same observations from a notoriously better base-line.

Had the observations been necessarily to be taken with a meridian circle, and necessarily to have occupied about three months, there might have been some reason for leaving the matter to fixed and established stations; but when they are more naturally to be made with an Equatoreal, as being small differences only, and might all be comprised most profitably within ten days or a fortnight, they come legitimately within the compass of astronomical expeditions; and, viewed in that light, the opposition of 1862 has this decided advantage over that of 1860, that it occurs at an equinoctial season of the year, when the light and heat circumstances of stations in high latitude both North and South will be very nearly similar.

In fact, at that season of the year and for the limited period demanded by equatoreal observations, there would seem to be no reason why an observer should not be sent to the North Cape, latitude $+ 71^\circ 10'$, and another to the southernmost island of Cape Horn, latitude $- 55^\circ 48'$, and thus observe with an intervening difference of 127°, in place of 94° only, the angle between Pulkova and the Cape.

There is little time left now to arrange such expeditions; but we often find, that it is precisely the shortness of time given wherein to perform any work, which calls out men's energies in accomplishing it; and, in such a point of view, there may be still quite time enough. On the understanding, too, that measures on, and near, the meridian, will be made at both stations, rather than at great hour-angles, a very portable folding dome, like Capt. Jacob's, might be easily arranged to allow of limited openings in definite directions, combined with full security to the instruments from inclement weather; and if only a week, indeed only three fine nights, could be secured about the time of maximum parallax, a remarkable micrometrical result might be obtained, and such a one as has not yet been seen in the history of Astronomy; obtained, too, not by anything so costly as what is usually called an expedition,

for the whole thing would rather partake of what the French would term "une *promenade* astronomique."

Even this time, too, might perhaps be shortened, and the result improved, by supplementing the hand-micrometer measures, with photographic pictures of *Mars* and the neighbouring stars, taken in the field of the telescope at intervals through the night on collodion plates, and submitted to screw and microscope measurement on returning to this country.

Royal Observatory, Edinburgh,
June 12, 1862.

Extract of a Letter from M. Winnecke to the Rev. R. Main, dated Pulkowa, 1862, *May* 30.

"I had the pleasure, a few days ago, to send you a short notice, in which a common plan of action is recommended for the observations of the approaching opposition of *Mars*. You, equally with myself, will be impressed with the importance of the questions at issue; and you will, I hope, at the same time, in looking through my proposals, see that they have not been made without mature consideration of the circumstances. I venture therefore to request that you will use your authority to set on foot, as far as possible, for the approaching opposition, a system of co-operation in relation to meridian observations of declination of *Mars*.

"I add here a few short remarks on some Variable Stars, which you will probably find an opportunity to communicate for the *Monthly Notices*.

"In No. 2, vol. xxii., of the *Monthly Notices*, which I received some weeks ago, Mr. Knott draws attention to the variable star R *Vulpeculæ* = Piazzi, xx. 457. The minimum is, according to his estimations, nearly coincident with a predicted maximum. In Pogson's Ephemeris my name is given as the authority for the time of maximum. I did certainly, two years ago, communicate to Mr. Pogson elements of this star; but I was afraid that an error of transcription had crept into them. My elements, which represent seven maxima, observed in the course of three years, with reference to Piazzi's estimations of magnitude, in August 1803, are namely

$$\text{Maximum, 1860, Nov. } 6 + 138^{d}\cdot 6\, n$$

(n being the number of periods from 1860, Nov. 6);

from which the maxima of 1861 fall on March 25, August 10, and December 27, and those next to be expected should occur on

1862, Sept. 30; 1863, Feb. 18, July 4, Nov. 20.

"I take this opportunity to communicate the following approximate first elements of some other stars, for which no data are given in Pogson's Ephemeris:—

T *Virginis*. 1860·0, $\alpha = 12^h\ 7^m\ 26^s$; $\delta = -5°\ 15'·5$.

Variable from the 8th mag. to less than the 13th.

Maximum, 1862, April 12 + $337^d\ n$.

The next maxima, 1863, March 15; 1864, Feb. 15.

T *Ursæ Majoris*. 1860·0, $\alpha = 12^h\ 30^m\ 1^s$; $\delta = +60°\ 15'·5$.

Maximum, 1860, Oct. 31 + $257^d\ n$.

Variable from 6·7 mag. to less than the 13th.

The next maxima, 1862, Dec. 11; 1863, August 25.

R *Camelopardali*. 1860·0, $\alpha = 14^h\ 28^m\ 28^s$; $\delta = +84°\ 27'·9$.

Maximum, 1861, August 17 + $265^d\ n$.

Variable from 7th mag. to 13th

The next maxima, 1863, Jan. 29, Oct. 21.

S *Cygni*. 1860·0, $\alpha = 20^h\ 2^m\ 34^s$; $\delta = +57°\ 35'·0$.

Maximum, 1861, Dec. 24 + $324^d\ n \pm$.

Variable from 9th mag. to less than 13th.

The next maximum, 1862, middle of November.

S *Cephei*. 1860·0, $\alpha = 21^h\ 36^m\ 54^s$; $\delta = +77°\ 59'·6$.

Minimum, 1862, Feb. 1 + $470^d\ n \pm$.

Variable from 8·9 mag. to 11·12.

The next minimum, 1863, May.

"The elements of this last star are little to be relied on, on account of the great difficulty of observing the blood-red variables. It appears, like T *Cancri*, to remain very long at its maximum, and to change its light slowly. For S *Leonis* (as the star at $\alpha = 11^h\ 3^m\ 36^s$, $\delta = +6°\ 13'·2$, ought to be called, since a star formerly so called is still not proved to be decidedly variable), the following elements will be somewhat more accurate:—

Maximum, 1860, Dec. 24 + $192^d\ n$.

The next maxima, 1862, July 23; 1863, Jan. 31.

Disappearance of B.A.C. 4923 *at the Moon's Dark Limb,* 1862, *June* 9, *observed at the Radcliffe Observatory, Oxford.* By the Rev. R. Main.

The star is a double star, the components being of about the 6th and 9th magnitudes. The time of disappearance of each star was instantaneous, and the observations were very good.

	h m s
Sidereal time of disapp. of smaller star	15 22 44·53
,, ,, larger ,, ...	15 23 14·03
Oxford mean time of disapp. of smaller star ...	10 10 40·03
,, ,, larger star ...	10 11 9·45
Greenwich mean time of disapp. of smaller star ...	10 15 42·63
,, ,, larger star ...	10 16 12·05

This star deserves the attention of astronomers, as, in addition to its duplicity, it has a large proper motion of $+0^s{\cdot}068$ in R.A., and of $+1''{\cdot}68$ in N.P.D.

I observed the distance and angle of position of the components of the double star on May 19, 1862; and I found for the distance (mean of six measures) $13''{\cdot}51$, and for the angle $283^\circ\ 51'$.

By comparison with Smyth's measures (*Cycle*, vol. ii. p. 329), it would appear that (unless he is in error) the star has been changing very rapidly both in distance and position-angle.

Observations of Jupiter's Satellites and of Saturn's Ring: Occultation of a Star by the Moon. By C. G. Talmage, Esq.

I send four observations of *Jupiter's* Satellites made at Nice, and three made at Mr. Coventry's Observatory, 5 Tavistock Square, and also an extract from my note-book concerning the peculiar appearance of *Saturn's* ring, about which so much has lately been said.

Occultation: Disappearance of Jupiter's First Satellite.

1862, March 17.

	h m s	
First contact	7 55 4	Nice M.T.
Central bisec.	7 56 39	,,
Total immersion	7 58 43·5	,,

Transit: Egress of Jupiter's First Satellite.

1862, March 18.

	h m s	
First appearance	7 20 56	Nice M.T.
Central bisec.	7 25 20	"
Last contact	7 29 49	"

Eclipse: Reappearance of Jupiter's Second Satellite.

1862, March 24.

$11^h\ 55^m\ 53^s{\cdot}74$ Nice M.T.

The time noted is exact; the satellite very distinct and beautifully defined; there appeared a great rupture in the southern belt near the centre, of a pyramidical shape, and a much darker colour than any other part of the belt.

Eclipse: Reappearance of Jupiter's First Satellite.

1862, March 24.

$12^h\ 13^m\ 10^s{\cdot}90$ Nice M.T.

The satellite rather faint.

Latitude of Nice	=	$43^\circ\ 41'\ 46''$ N.
Longitude ditto	=	$29^m\ 7^s$ E.

Nice, February 24, 8^h, 1862.

The night was not very fine, although *Saturn* appeared very distinct, and the peculiar marking on the ring was well defined, presenting a double serrated edge, with a distinct black line between the upper and lower edges; and the body of *Saturn* had, if I may use the expression, a dirty look. I only mention this, as I have not seen any observations of the kind prior to the above date, which I think shows that we are favoured with a very fine atmosphere, to see that peculiarity in our small glass.

Occultation: Disappearance of Jupiter's Second Satellite.

1862, May 2.

$8^h\ 58^m\ 22^s{\cdot}30$ G.M.T.

Eclipse: Reappearance of Jupiter's First Satellite.

1862, May 2.

$10^h\ 12^m\ 8^s{\cdot}30$ G.M.T.

Eclipse: Reappearance of Jupiter's Second Satellite.

1862, May 20.

$8^{h}\ 21^{m}\ 49^{s}{\cdot}80$ G.M.T.

Latitude of Tavistock Square Observy. 51° 31′ 30″ N.
Longitude ditto $0^{h}\ 0^{m}\ 29^{s}{\cdot}7$ W.

Mr. Talmage sent also the following observation,

Occultation: Disappearance of B.A.C. 4923, *June* 9.

This is a very fine double star of the 6th and 8th magnitudes. The following are the noted times of disappearance:—

	h m s	
Small star, 8th mag.	10 17 24·50	G.M.T.
Large star, 6th mag.	10 17 52·80	„

At the time of reappearance, a thin cloud hid the small star, but the larger one came out sharp and well defined, instantaneously at

$11^{h}\ 29^{m}\ 7^{s}{\cdot}00$ G.M.T.

Results of Meridional Observations of Small Planets, and Phenomena of Jupiter's Satellites; observed at the Royal Observatory, Greenwich, during the month of May, 1862.

(*Communicated by the Astronomer Royal.*)

Hebe ⑥.

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, May 12	13 36 58·6	16 59 12·55	90 40 15·52
20	12 59 4·9	16 52 45·10	90 12 48·56
31	12 5 37·0	16 42 30·58	89 53 9·54

Flora ⑧.

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, May 5	10 38 38·6	13 32 47·41	89 44 50·77
19	9 33 56·7	13 23 6·65	89 25 36·17
20	29 29·5	13 22 35·25	89 25 37·88

Melpomene (18).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, May 16	11 15 24·6	14 53 1·57	90 18 6·91
19	11 0 53·2	14 50 17·46	90 8 1·20
20	10 56 3·7	14 49 23·72	90 4 58·46

Massilia (20).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, May 12	12 35 23·6	15 57 27·77	109 53 30·07

Euterpe (27).

Mean Solar Time of Observation.		R.A. from Observation.	N.P.D. from Observation.
	h m s	h m s	° ′ ″
1862, May 5	10 15 13·9	13 9 18·80	94 51 28·60
20	9 9 4·3	13 2 6·71	94 21 36·86

All the observations of N.P.D. have been corrected for Refraction and Parallax.

No Occultations of Stars by the Moon were observed.

Phenomena of Jupiter's Satellites.

Day of Observation.	Satellite.	Phenomenon.	Mean Solar Time.	Observer.
1862.			h m s	
May 2	II	Occ. disapp. first cont.	8 55 2·0	D.
,,	II	,, bisection	8 56 47·0	D.
,,	II	,, last cont.	8 58 47·0	D.
,,	I	Eclipse, reappearance (*a*)	10 12 23·3	D.
17	I	Egress, bisection	10 14 48·0	C.

(*a*), Very hazy; the observation not very satisfactory.

The initials D. and C. are respectively those of Mr. Dunkin and Mr. Criswick.

Description of a New "Aplanatic" Eye-piece for Telescopes. By T. W. Burr, Esq.

Those astronomers who are also microscopists are probably acquainted with an eye-piece for the microscope known as "Kellner's," or the "Orthoscopic," which offers the advantage

of a much larger field of view than the Huyghenian of corresponding power, and with equally good definition. It consists of a double convex crossed lens for field glass (that is, a lens having surfaces of different radii, the most convex side being towards the objective), and a meniscus of great convexity and small concavity for eye-glass. There is no stop in this arrangement.

Having experienced the benefit of this construction with the microscope, I was desirous of applying it to the telescope; and while trying the "Kellner" belonging to my microscope on the telescope of my Equatoreal, with which it produced only a low power, and when about to have another made for the purpose, I was informed that Mr. Thornthwaite (of the firm of Horne and Thornthwaite, Newgate Street,) had improved the "Orthoscopic" microscopic eye-piece, by substituting an *achromatic* plano-convex lens for the meniscus. The eye-glass, in his modification, consists of a double convex crown-glass lens and a plano-concave of flint-glass, forming a combination similar to one of the pairs of an achromatic microscope objective; and this construction (the field-glass remaining a crossed double convex) preserves the advantage of the large and flat field, with better definition and freedom from colour, which has induced the inventor to call it the "Aplanatic" eye-piece.

Having used this form in a microscope, I at once decided to adopt it for my telescope experiments; and therefore requested Mr. Thornthwaite to make me a suitable eye-piece, which, for the purpose of comparison, I required should be of the same power as my third Huyghenian, which, measured by Ramsden's Dynameter, gives with my object-glass a power of 123. The new eye-piece constructed for me, measured in the same way, gives 125 for its power,—a sufficiently close approximation; the slight difference being against the new combination as to size of field.

I have submitted this eye-piece to a careful and lengthened trial, and can now confidently recommend it to observers, as possessing the very great advantage of a much increased field, as compared with the Huyghenian of the same power. This is at once evident on looking at the Sun or Moon, when at least one-third more of the disk of either body is visible with this eye-piece, than with the corresponding Huyghenian. For instance, with my telescope and the ordinary eye-pieces; while a power of 60 includes the whole disk of either Sun or Moon, 80 fails to do so; and with 123 on the Moon, the field includes from the South Pole to about *Plato*, or from the North Pole to near *Bullialdus*, or in longitude, from the eastern border to *Copernicus:* while with the "Aplanatic," of even a little more power, the merest film of one edge is left unseen, and on one favourable occasion, the full Moon was entirely included. The

definition is also quite equal to the Huyghenian at all parts of the field.

The benefit of this eye-piece is also strikingly apparent in viewing clusters, such as the *Pleiades*, *Presepe*, and others; in which small stars are brought up by the increase of power and light, without losing the advantage of a large field; and in the Great Nebula of *Orion*, the effect is very beautiful, allowing the employment of a power which before was disadvantageous, as it made the object dim, and contracted the field; which is now large, and the nebula very brilliant. The division of double stars is rendered easier by this eye-piece, and the range of the telescope among small ones extended. For example, persons who could not see ε *Lyræ* quadrupled with the Huyghenian of 123, had no difficulty in doing so with the Aplanatic, while the detail of the planets, and generally every object, is more readily appreciated.

I send herewith sketches of the construction of the three forms of the eye-piece, viz. the Huyghenian, Kellner's, and the Aplanatic, for comparison; and also place the instruments themselves before you.*

Highbury, June 10, 1862.

On the Appearance of Jupiter without a Visible Satellite, Sept. 1843. By the Rev. W. R. Dawes.

It has been lately suggested to me by the Astronomer Royal, that a remarkable phenomenon, which I happened to observe many years ago, ought to be recorded where it might be readily referred to; and that in fact there could not be a more suitable repository for it than the Royal Astronomical Society. I have much pleasure in acting upon this suggestion, being assured that no other apology can be needed for offering to the Society an observation which was made nearly nineteen years ago. I refer to the appearance of *Jupiter* without a visible satellite in September 1843. The observation of this rare phenomenon was immediately afterwards communicated to *The Times* newspaper in a letter, which principally referred to another Jovian phenomenon, namely, the dark transit of one of his satellites. I supposed at the time that the solitary appearance of *Jupiter* would be extensively observed; and that many communications would be made to the Society by observers possessing the means of more accurately noting the *times* of the

* The sketches and instruments were exhibited at the Meeting of the Society.—Ed.

different occurrences than I happened to have on that occasion. Had I been aware that not a single notice of it would be sent to the Society, I should certainly have made a communication, though in some respects imperfect, in time for the first meeting of the then ensuing session. I mention these circumstances as furnishing the only apology I can offer for having omitted to send some account of the observation to the Society immediately.

On 1843 September 27, in the early part of the evening, *Jupiter* appeared with all his four satellites very near him, and all approaching him. The *fourth* satellite passed on to the disk soon after $8^h\ 30^m$ G.M.T. This I observed at Mr. Bishop's observatory, with his equatoreal refractor of 7 inches aperture, by Dollond. At about $9^h\ 50^m$ I again directed the telescope to the planet, which very soon afterwards passed behind a tree; and as the state of the air was too unfavourable for observations of double stars, in which I was almost entirely occupied, I repaired to my own residence in Park Place, and turned upon the planet a very excellent 43-inch refractor of 2·7 inches aperture by Dollond, power 113.

Soon after 10^h G.M.T. (time not exactly noted) the *first* satellite passed on to the disk of *Jupiter*.

At $10^h\ 35^m \pm$ the *second* satellite was occulted.

At $11^h\ 55^m \pm$ the *third* satellite passed on to the disk.

Jupiter was then without a visible satellite.

At $12^h\ 30^m \pm$ the *first* satellite passed off the disk.

At $13^h\ 30^m \pm$ the egress of the *fourth* satellite occurred.

It appears, therefore, that for about an hour and twenty minutes the *third* satellite was the only one visible. For about thirty-five minutes *Jupiter* was without any visible satellite. And after the egress of the *first* satellite it was the only visible attendant for rather more than an hour.

The uncertainty of the times specified arises from the fact, that those which were noted at all at the instant of the occurrence, were taken from a pocket-watch, the precise error of which was unknown. And in one instance, the time was estimated from the supposed interval which had elapsed between the occurrence of the phenomenon and the procuring of a light, which was not at hand at the instant. It was this uncertainty which deterred me from presenting to the Society an account of the observation, hoping that others would be presented containing details as to time more accurately noted.

Hopefield Observatory, Haddenham, Thame, May 1862.

On the Periodical Changes in the Belts and Surface of Jupiter. By W. Huggins, Esq.

In addition to the ceaselessly varying appearances of the surface of the planet *Jupiter*, there would seem to be great periodic changes occurring in the conditions on the planet, of whatever nature those conditions may be, which give rise to the phenomena visible to us. It would seem therefore to be of considerable interest to bring together for careful comparison drawings of *Jupiter*, exhibiting in sufficient detail the more remarkable of the forms which the belts and spots assume at different epochs. For example, the comparatively inactive state of the planet during 1858 and 1859, contrasts in a very marked manner with the strongly defined and actively changing dark belts of the present year. In the hope of exciting attention to these periodical changes of *Jupiter's* surface, and as a humble contribution towards the commencement of such a series of representations of *Jupiter*, I have sent herewith a few drawings, exhibiting in considerable detail, and I believe, with great fidelity, the more characteristic of the appearances of *Jupiter* during the seasons of 1858, 1859, and 1860.* Object-glass 8 inches diameter, and power from 150 to 400.

Upper Tulse Hill.

Transit of Titan's Shadow. By S. Gorton, Esq.

Mr. Dawes' account, in the last number of the *Monthly Notices*, of this interesting phenomenon on the 15th of April, concludes by stating that, in his opinion, "from the great size of the shadow, a 5-foot refractor of $3\frac{3}{4}$ to 4 inches aperture would have shown it."

This is completely verified by my observation of the same evening, a short notice of which was read at the meeting of the Society on the 9th May. My telescope is of 4 feet focal length and $3\frac{1}{8}$ in. aperture. I observed with a power of 170, and afterwards with one of 100. At the time I left off observing, the shadow of *Titan* was near the centre of the disk of *Saturn*, and was almost as easy to be seen with the latter power as one of the shadows of *Jupiter's* satellites in transit.

Downs Road, Clapton, June 19, 1862.

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* The drawings were exhibited at the Meeting.—Ed.

On the Appearance of Saturn's Ring, 1862, *May* 13, $8^h\ 45^m$ *G.M.T.* By W. R. Birt, Esq.

On the evening above specified I had an opportunity of observing *Saturn* at this interesting epoch, with an 8-inch object-glass, which Mr. Slater is now constructing for T. Coventry, Esq., and also with the large refractor of nearly 15 inches aperture.

The state of the atmosphere was not over favourable for so delicate an observation, nevertheless, during fits of good definition, which were not of long duration, I saw very distinctly the fine ansæ broken into minute points or beads of light. It was difficult to get a sufficiently steady interval to count these beads, but the impression I had as to the number of the most prominent was that there were about seven, four on the following and three on the preceding ansa; Mr. Slater noticed five on the following ansa. The following ansa was the longest. On one occasion I obtained a very fine view, when they appeared as *irregularities or projections on the illuminated plane of the ring*, as if such projections were more directly illuminated, and consequently reflected more light than the obliquely illuminated plane of the ring. I did not obtain a confirmation of this interesting appearance. The ring of the shadow formed a somewhat narrow dusky line across the disk, the northern portion being rather the darkest. Mr. Talmage, who was present, saw the fine line of light separating the two, but when I inspected the planet the atmosphere was not sufficiently fine to allow me to witness this interesting phenomenon. Mr. Slater, who observed the beads with a 10-inch object-glass on the 8th of May, at Sheffield, witnessed the phenomena above described, the only exceptions being the number of beads on the following ansa, and the number on the preceding, which he did not estimate.

On the 1st of May Mr. Slater witnessed the transit of the shadow of *Titan* across the disk of the planet.

On some Phenomena attending the Disappearance of Saturn's Ring, May 19th, 1862. By W. Huggins, Esq.

The following notes may perhaps be of some value in support or otherwise of more complete observations of *Saturn*, during a period of so much interest as that through which the planet has just passed.

May 2d. A brief separation of the clouds showed *Saturn* with two bright dots of light upon the eastern ansa of the ring. These were at first taken for satellites. As the haze thickened

and the ansæ faded from view, the contrast between these bright points and the fading ring increased until the ring was lost, when the dots of light alone continued visible as faint and badly defined satellites. As there were no satellites near these positions on that evening, these appearances corresponded probably to the "bright points" seen on former occasions. Vide *Monthly Notices*, vol. x. p. 47.

May 12th. The points of light were again faintly visible, and were best seen when the eye was not directed to them. Passing masses of haze brought them out in strong contrast with the ring, as the pale light of the ansa seemed to suffer greater diminution in proportion than the brighter points.

May 13th. On this evening they were distinctly traced on the eastern ansa to correspond in position with the inner and outer edges of the extremity of the ring. One was seen at the termination of the dark space between the ball and the ring, and the other at the extremity of the visible portion of the ring.

On the 16th the ansa still continued steadily visible, but no indication of these bright points could be seen. The colour of the ansæ, that is, of the surface of the ring seen very obliquely, was a deep bluish purple. A badly defined line of faint shading was suspected across the ball close to the southern edge of the projected ring, in the position in which the shadow of the ring was looked for.

Since that date up to this time, June 10th, no trace whatever of the expected shadow of the ring upon the ball can be detected, though carefully searched for.

On the 17th, 18th, and 19th of May, the ansæ were still seen, though with increasing difficulty, and therefore never totally disappeared.

On the 20th the ansæ appeared of a beautiful dark blue colour, scarcely distinguishable from the dark blue of the sky, which contrasted strongly with the yellow light of the ball.

Upon several occasions, May 18th especially, little roughnesses, resembling miniature satellite-shadows, were suspected on the southern edge of the ring upon the ball, but in every instance these disappeared entirely with the employment of powers from 600 to 950. With these powers, in moments of best vision, the edge of the ring was seen perfectly even and unbroken.

May 17th was cloudy, but at $11^h\ 30^m$ the shadow of *Titan* was seen projecting rather more than half its diameter from the northern edge of the ring.

June 2d. The weather was equally unfavourable, at $10^h\ 45^m$ a brief separation of the clouds showed *Titan's* shadow in contact with the southern edge of the projected ring.

Object-glass 8 inches diameter. Power from 200 to 950.

June 11, 1862, *Upper Tulse Hill.*

Saturnian Phenomena. By the Rev. W. R. Dawes.

The night of May 17 was remarkably favourable, especially the earlier part of it, and afforded a very fine view of the expected transit of the shadow of *Titan* across the disk of *Saturn*.

Previously to the ingress of the shadow, I examined the planet most carefully with a power of 620 on my $8\frac{1}{4}$-inch object-glass, which, when twilight had sufficiently faded, was well borne — the features of *Saturn* frequently coming out with beautiful distinctness, and the edge of the disk being sharply defined. The arms of the ring were scarcely at all visible; a very faint gleam of coppery light, at moments of finest vision, being the only indication of its existence beyond the disk of the planet. It has since been seen, on several occasions, much more plainly. On the disk the projected ring appeared as a very dark line a little north of the equator, and of uniform breadth. But I was much surprised that, under the finest definition with this high power, I could discern no trace of the *shadow of the ring*. I expected to see it, if the atmospheric circumstances were sufficiently good, as an *exceedingly fine black line*, stretched across the disk about a quarter of a second to the south of the inner edge of the projected ring; and that the shadow of the satellite would travel almost centrally on the black line — a great part of it, however, falling on the southern portion of the ring. But no such thing was to be found.

Having applied the parallel-wire micrometer with a power of 480, with which the planet was usually very sharply defined; as the expected time of ingress approached, I kept my eye steadily fixed on the eastern extremity of the dark line caused by the projected ring.

At $9^h\ 35^m$ G.M.T., the end of this dark line was observed to be decidedly enlarged, especially on its *northern side* (instead of the *southern*, as was expected).

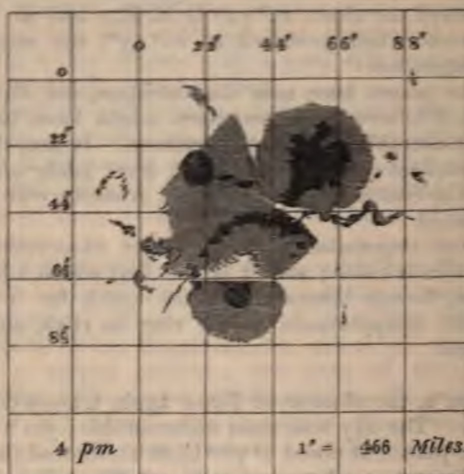
At $9^h\ 37^m$, the shadow was judged to have just completed its ingress.

At $9^h\ 40^m$, a narrow thread of light was perceived outside the shadow, and on the northern side of the projected ring. It then became obvious that the shadow projected rather more than half its diameter to the *north* of the ring, and so little to the *south* of it that only under the finest views could any projection on that side of it be certainly perceived.

At $9^h\ 52^m$, I carefully estimated that six-tenths of the diameter of the shadow projected from the northern edge of the ring.

After this time the state of the air greatly deteriorated, and I obtained with difficulty some micrometrical measures with powers 375 and 286. The result gave the distance of

until nearly in contact; a day or two after, on the 7th, one of the circular spots appeared to be cut in half and obliterated, having a sharp defined edge; on the 8th, a second circle was similarly cut to a straight line, the other half coalescing with a



spot near it; on the 11th I saw it again for a few minutes, when the whole group was much more detached, and, with the exception of the largest spot, the circular character had entirely passed away.

Telescope, 6 inches aperture. Power, 120.

At the close of the evening meeting Mr. Carrington explained and illustrated by diagrams the process which he had lately made use of in obtaining the corrections required by his provisionally assumed elements of position of the solar equator. He stated that 86 series of observations alone were found suitable out of about 1000, which his records comprise, it being necessary to reject the greater part on account of the mutual action of one spot on another in its neighbourhood, and to use only isolated nuclei of small extent and regular form. He showed how the required corrections were deducible from the quantities X and Y, found from an equation corresponding to each observation of the form,

$$\delta' - \delta = X \cos \alpha - Y \sin \alpha,$$

in which δ' is N.P.D., found by use of the provisional elements, δ the true N.P.D., and α the heliographical longitude of the

spots, reckoned along the solar equator from the ascending node. The values of the elements which he has found from the 86 series are

$$I = 7° \ 15' \quad \text{and } N = 73° \ 40' \text{ for } 1850{\cdot}0,$$

the values of M. Laugier, deduced about 1841, from 26 series, being,

$$I = 7° \ 9' \quad \text{and } N = 75° \ 8' \text{ for } 1840,$$

and those of Dr. Böhm from 19 series being

$$I = 6° \ 57' \quad \text{and } N = 76° \ 46' \text{ for } 1877,$$

The rotation per diem was exhibited in a tabular form for every 5 degrees of declination, as deduced directly from numerous singly determined values in each parallel. The formula

$$865' - 165' \sin^{\frac{7}{4}} \text{lat.}$$

satisfies the whole so nearly, that although it can only temporarily be regarded as an empirical result waiting for theoretical explanation, it is difficult to see how any improvement in it can be effected as a representation of the numbers. Mr. Carrington claims the term in latitude of the solar rotation as one of the chief results of his long-continued observations of the Sun, the whole of which are nearly ready for the press. It would be anticipating the intended future publication to give more than the bare results in the present place.

In reference to the remarks made in the *Monthly Notices* for February 1862, pages 124 and 125, Mr. Pogson, writing through the Astronomer Royal, desires to make it known that he has undertaken to extend Professor Argelander's noble work southward, by a complete Celestial Survey of the Southern Heavens, as soon as the Variable Star Atlas shall be out of hand. This Survey must, in the first instance, be limited, in its southern direction, by the southern horizon of Madras; but Mr. Pogson looks hopefully to the possibility of ultimately completing it by an expedition to Australia.

Mr. Pogson hopes to begin this work early in 1863; but, he remarks, the limits of time and money, as defined by Professor Argelander's experience, will not apply to a similar work undertaken in an exhausting tropical climate with native assistants.

G. B. Airy.

1862, *June* 17.

RECENT PUBLICATIONS.

An Historical Survey of the Astronomy of the Ancients. By the Right Hon. Sir George Cornewall Lewis. London, 1862.

The history of Astronomy has numerous points of contact with the general history of mankind; and it concerns questions which interest a wider class than professed astronomers, for whose benefit the existing histories have been mainly composed. This remark applies with especial force to the early periods of astronomical observation and science. It has in consequence appeared to the author that an attempt might advantageously be made to treat the history of Ancient Astronomy without exclusive reference to physical science, and without any pretension on his part to a profound and comprehensive knowledge of modern mathematical astronomy. As the accounts of Greek Astronomy, though often meagre and fragmentary, afford in general a firm footing to the historian, and enable him to fix with confidence all the principal stages in its progress, it was considered desirable to begin with this branch of the subject, and afterwards to attempt to determine how far the Greeks derived their astronomical knowledge from other nations, and were learners, instead, as was their custom, of being teachers. And, following this plan, the Astronomy of the Egyptians and Assyrians is first discussed in the latter half of the volume. In support of the alleged antiquity of the astronomical science of these empires, appeal is usually made to their primitive civilisation, and their list of kings, reaching through long lines of consecutive dynasties. It became necessary, therefore, to advert to the early history and chronology of these countries, for the purpose of ascertaining how far they serve to prop up the tottering edifice of Assyrian and Egyptian science. And, as may be conjectured, the conclusion of the inquiry is not in favour of the reliability of these accounts; in particular the author's arguments go to throw doubt upon the possibility of reading and correctly interpreting the Egyptian hieroglyphical inscriptions. The origin of Astronomy is sometimes traced to the Phœnicians, whose commercial wants and nocturnal navigation must, it was supposed, have led to a knowledge of the subject: the concluding chapter of the work relates to the navigation of the Phœnicians, their alleged voyages to Britain and the Baltic for tin and amber, and the supposed circumnavigations of Africa. These subsidiary inquiries form not the least interesting part of the volume.

Recherches Astronomiques de l'Observatoire d'Utrecht. Publiées par M. Hoek, Directeur de l'Observatoire et Professeur à l'Université. Première Livraison. 4to. La Haye, 1861. Pp. 1–72.

The work is intended to be a collection of theoretical and practical researches too extensive for an Astronomical Journal, and to be continued at intervals, as the matter presents itself. The present number contains a theoretical investigation of the influence of the motion of the Earth on the fundamental optical phenomena connected with Astronomy—the undulatory theory of light being made use of in the investigation. There are four chapters, relating respectively to Reflexion, Refraction, Aberration, and Astronomical Methods and Instruments; with some additions. One of the conclusions appears to be, that the motion of the Earth produces a sensible modification of the law of refraction.

Die Astronomische Strahlenbrechung in ihrer historischen Entwickelung. Von Dr. C. Bruhns, Astronom der neuen Sternwarte und Professor an der Universität zu Leipzig. 8vo. Leipzig, 1861. Pp. 1–182.

The work relates to Astronomical Refraction, and is divided into two sections—the first containing the history, from the discovery of the phenomenon to the end of the eighteenth century; the second relating to the researches which belong to the present century: the various theories are reproduced, and the mathematical developments exhibited in abridged and simplified forms, with some original investigations. The author proposes to give in a separate treatise the application to observations, and the Tables. There is, at the end of the Preface, a list of the works consulted, which is a convenient *resumé* of the literature of the subject.

Dr. Bruhns, who is the first Director of the new Observatory at Leipzig, has also published

Geschichte und Beschreibung der Leipziger Sternwarte, zur Eröffnung der neuen Sternwarte am 8 *November* 1861, *herausgegeben von Dr. C. Bruhns. Mit fünf lithographirten Tafeln.* Leipzig, 1861.

The new Observatory is situate near the town, in a somewhat elevated position in the Johannisthal. The latitude and longitude, as deduced from those of the old Observatory of the

Pleissenburg, are—latitude 51° 20′ 9″·8 N., longitude 49^{m} 33^{s}·6 E. from Greenwich. The detailed description of the instruments is reserved until the completion of the great Equatoreal in course of construction by Pistor and Martins, and the publication of the first volume of Observations.

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Printed by Strangeways and Walden, Castle St. Leicester Sq. and Published at the Apartments of the Society, July 16, 1862.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

Vol. XXII. *Supplemental Notice.* No. 9.

On the Great Comet of 1861.* By the Rev. T. W. Webb.

Though the observations which I was able to obtain of the physical aspect of the late splendid Comet are in several respects far from complete, I am induced to beg permission to submit them to the notice of the Astronomical Society, by the conviction that, in the case of objects so ill-defined and little understood, the accumulation and comparison of evidence will be likely to lead to a more satisfactory result upon the whole than might be attained, even under the most favourable circumstances, by any one observer, unaided and unchecked by independent testimony.

The observations which follow will be rendered more conveniently intelligible, if, instead of being retained in the form of a diary, they are arranged under separate heads, corresponding with the general structure of the comet.

The same telescope was employed throughout, having an excellent object-glass by Alvan Clark, of 5½-inches aperture and 7 feet focal length.

I. *The Nucleus.*— On the evening of June 30, when, in common with the great majority of observers, I caught the first surprising view of this grand comet, the nucleus, a mere point in the comet eye-piece, and gradually opening and softening with increase of magnifying power, was expanded with about 460 into a fine luminous disc, estimated by a very rough guess at about 2″† in diameter, having an uniformly distributed golden light, intermediate probably between that of *Venus* and *Jupiter;* and a very ill-terminated, but still definite, limb, which would, no doubt, have been much more distinctly marked at a higher altitude. It was quite circular, and showed no tendency whatever to a phasis.

* Comet II. 1861.

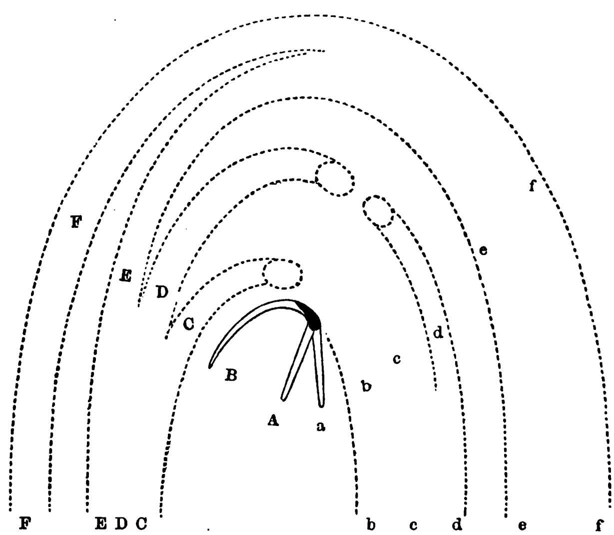
† This, I have since thought, was underrated.—T. W. W.

July 1 having been cloudy, on July 2 the nucleus was found to be equally brilliant, but already much smaller, and less abruptly distinguished from the adjacent luminosity, though the sky was not unfavourable.

July 3, in earlier twilight and a more vaporous atmosphere, the nucleus is entered as "small, dull, and ill-defined," with 460, though still a sharp and vivid point with 110.

July 4, the nucleus was estimated as not exceeding 0″·5, but this was probably in defect; and it subsequently proceeded in a course of degradation, till, on July 15, it was "extremely dim and nebulous" with 460, and even with low powers, though still vivid, was evidently losing its sharpness.

II. *The Envelopes.*— The number and complex arrangement of these luminous veils on June 30, as seen in the comet eye-piece, with a field of about 52′, and a power of 27, produced a singular as well as magnificent effect: it was as though a number of light, hazy clouds were floating around a miniature full moon. Portions of six could be more or less distinctly traced, as in fig. 1. The innermost of these (A a in the key) was very narrow and short, faint on the left hand,



but brighter on the right in the inverted view, and coming up close to the nucleus. The second was a parabolic arc (B b), in which the nucleus stood, but at some little distance from the vertex. The portion of it extending from the nucleus towards the inverted left, or orbitally following side, exhibited the most

vivid light of any of the envelopes, especially towards the nucleus, from which it seemed to issue straight out as an actual jet or stream, strongly luminous even with a power of 460. Its opposite branch beyond the nucleus was so much more faint and confused, that at the time its character was mistaken; it was not recognised as the prolongation of the same arc, which was erroneously, as I believe, referred to the right side (a) of the innermost envelope; nor was the mistake perceived till the next observation made the true structure of the head apparent, according to the best judgment which I could then form. It may here be remarked that these two interior veils were both in apparent contact with the nucleus, from which all the outer ones were clearly separated. The third envelope (C c) was only traceable on the left side, the opposite branch being merged in a diffuse haze. A little to the left of the probable direction of the radius vector it was kindled up into a small, bright, ill-defined cloud, more luminous than the rest of the curve, but not attaining the condensed light of the parabola next within it. The darkest portion of all the vacancies in the head was the space comprised between the left side of this envelope and the corresponding branch of the bright parabola within it, towards the visible termination of the latter. The 4th envelope (D d) took a considerably wider sweep: on the left hand it was confounded with the previous one, but arose out of it towards its vertex, leaving an interval of fainter light: on the right hand, according to the sketch taken at the time, the envelopes 2, 3, and 4, were all merged in one continuous veil, the outer and inner boundaries of which were alone distinguishable. Somewhere near the direction of the radius vector, as conjectured from the position of the innermost envelope, there was an indentation in the parabolic outline of D d, on each side of which there was a patch of more condensed light — that on the right was not very conspicuous, but the one to the left was much more luminous, exceeding in size and brightness the patch in the envelope C c, and forming a striking feature in the head: a line through this patch, and that in C c, passed far to the left of the nucleus. The 5th envelope (E e) was a faint, narrow stream, undistinguishable from D d to the left, but separated widely towards the right by the comparatively dark space which caused the indentation already mentioned in D d. F f, the 6th, a similar narrow faint stream, had a distinct existence to the left, beyond a vacant interval, but was blended with the 5th towards the vertex of the parabola. Outside of these lay a great extent of scattered nebulous light on every side, fading gradually into the clear sky. None of the six envelopes could be traced for any distance backwards, all of them becoming speedily lost in the diffused train.

Fig. 5 represents the nucleus and brilliant jet, as seen with a power of 460; sketched, however, merely from memory.

On the next night of observation, July 2, the envelopes were found to be considerably changed, as in fig. 2, and still more confused on the right or orbitally preceding side of the head. Each branch of the first or innermost envelope was now equally faint: the great curve of No. 2 had become distinctly thicker, its prolongation beyond the nucleus continuing very dim: 3 and 4 were blended into one broad veil, all the luminous patches in them had faded, and the included area had become filled with nebulous light, stronger than the remoter parts of the head; the indentation in the outer boundary of No. 4 could be still traced, and the definite outline of the vertex of this envelope, contrasted with an exterior area of comparative darkness, was one of the most remarkable features of the head. This dark space was soon lost towards the right in confused nebulosity; its left end was at first supposed to be continuous with the broad vacancy exterior to the parabolic arc No. 2; but it was subsequently thought to be cut off from it by a feeble remnant of Nos. 3 and 4. Envelopes 5 and 6 were now combined into one broad veil, which passed away into the train.

July 3. I have no note of the aspect of the envelopes, having my attention drawn to other points, in a sky full of strong twilight and haze.

July 4. There is a comparatively dark and tolerably defined space in the head, as in fig. 3, exterior to the sector now formed, about one-third of its breadth, encompassing it as far as it is distinctly marked, and prolonged a little beyond it on the lower inverted side. Outside of this vacancy all is diffuse nebulosity, with some doubtful traces of streakiness, as if envelopes still existed there, not separately distinguishable. The orbitally preceding or south side is especially confused and ill made out.

July 5. The dark area is nearly obliterated, but the coma exterior to it seems streaky, as though composed of a number of narrow veils.

July 8. No envelopes remain.

III. *The Luminous Sector or Fan.*—This, as immediately connected with the nucleus, might have been described before; but, as its formation was at first incomplete, the observations may be more intelligible from its postponement. The first indication of its existence was the very intense light of that portion of the parabolic arc, or second envelope, which seemed to issue from the left side of the nucleus. This was very conspicuous in the first observation, and probably continued traceable, with little alteration, to the last. It has been drawn in fig. 1, as represented in the original sketch, coinciding with the external edge of the parabola; but I could not be confident as to this, not having expressly attended to the point; and from subsequent appearances it is more likely that it followed the interior curve of that envelope. It had not been noticed

in sketching with the low power of the comet eyepiece, about 27, but was clearly brought out with powers of about 110, 170, 275, and even 460, as a strong curved ray or vivid stream, actually emanating from the material of the nucleus, and gradually losing itself in the envelope.

July 2. The sector was more fully developed; in the comet eyepiece it was hardly discernible from the irradiation of the nucleus; but 110 brought it out beautifully, and it was visible even with 460. It extended, as in fig. 7, through about 125°: the upper inverted edge, which was the brightest part, and barely distinguishable from the nucleus at its origin, standing at an angle of about 190°; the other edge, shorter, less defined, and apparently a little curved, at about 315°; a portion of the included area preceding the nucleus was fainter than the rest. The extent of the upper cusp towards the Sun might be $\frac{1}{7}$th of the distance from the nucleus to the indentation in the envelope No. 4.

July 3. The sector has a greater angular extent than last night, its edges standing at about 170° and 330°. It is very conspicuous in strong twilight, and has a radiated appearance, which had been suspected, but not verified, last night: the edge directed towards the Sun has lost its vivid light, and the brightest portion, which but little exceeds the rest, is a ray standing at about 225°, as in fig. 8. The edges sometimes appear a little concave.

July 4. The fan radiates like an electric brush, strongly reminding me of a similar appearance in the last return of the Comet of Halley. It must have gained considerably in breadth, as it is now well seen in the comet eyepiece. I estimate its extent at more than twice that of July 2. It is very well shown in the micrometer eyepiece, power about 55, with which some measures are attempted. The radius towards the Sun, so bright on July 2, has now become very feeble, and has also advanced in angular position, as in fig. 3; thence the area brightens to a distinct beam, with a thicker and denser extremity; next to this is a space of feeble light, running up far towards the nucleus; and, further on, the circular limb seems to be indented, so as to make the form of the north cusp sharp and long: an appearance increased by the backward curvature of the hinder boundary of the sector. But, excepting the beam with its broader end, which was sufficiently evident, these details were delicate and difficult. The measures of position, such as they were, gave for the south edge 207° (extremely uncertain), the luminous beam 251°, the north edge about 340°. The length of the beam, from its time of passage, appeared to be about $1\frac{1}{2}$ minute of arc.

July 5. The comet eye-piece showed the south edge of the fan more opened backwards, so that its position was more symmetrical; the luminous beam was broader, but less distinct.

July 8. The sector has nearly lost its circular boundary, and it fades down into the coma; but it is still visible, of a dull yellow hue, with 460: a mean of three bad measures of position gave for the south edge, 227°; for the luminous beam, 271°.

July 10. The sector seems to stand as obliquely as in the last observation; its circular boundary has disappeared, and the stronger ray is very obscure.

July 15. Hazy; sector ill-defined, visible with 460, but contracted in angle, and of a brownish yellow hue.

July 16. Much clearer; the increasing density of the adjacent coma barely leaves a separate existence to the sector, which, however, in the present sky, has recovered its angular extent.

IV. *The Coma.*—This great mist faded away so imperceptibly that no attempt could be made to sketch its boundary; but I regret that I did not endeavour to form some idea of its extent at its first appearance.

On July 4 the whole diameter of the head was very roughly estimated at 20′; July 10, 18′; July 15, 13′. My general impression, towards the close of the observations, was that it had increased in density and brightness as it diminished in extent: this seemed evidently the case on July 16, as, even with so high a power as 460, it was very conspicuous around and beyond the sector. Its most remarkable feature has been its change of colour. On June 30 the whole comet had a strong golden hue. July 10. I have entered it as distinctly white to the naked eye, and in the comet eyepiece tinged with blueish green or greenish blue. This hue was subsequently confirmed with suitable powers on the 15th, the nucleus appearing to have a greenish yellow cast. Considerable allowance must, of course, be made for the removal of the object from the ruddy vapour of the horizon, but still I think the fact of the change is at least highly probable.

V. *The Tail.*—This magnificent appendage was chiefly remarkable for its near approach to us, and consequent apparent length, being far inferior in density and definition to that of "the Donati."

On June 30 I traced it beyond the zenith, giving an extent of at least 90°. It widened out from the nucleus for some degrees, probably to a breadth of 3° or 4°, but was very undefined, and equally so on either side. The east edge appeared to strike off from the coma for a few degrees at a greater angle of divergency, but could not be traced by me as a separate branch; nor did I perceive, probably owing to the intervention of trees, the very interesting ray on that side, which, according to a communication and sketch with which I have been obligingly favoured by George Williams, Esq., of Liverpool, extended from the neighbourhood of the Comet's head as far as, and across, the stars of *Cassiopea:* the brightest part of

this beam, it is stated by the observer, was at some distance from the Comet, and it appeared to recede from it until it was altogether lost.* The main stream was considerably convex towards the west, pointing at its origin to the left of *Polaris*, and subsequently bending back so as to involve that star, which was in its centre about 11^h; but thence it appeared to the eye of another person, as well as my own, to take a fresh course, directed straight from the nucleus towards β and γ *Lyræ*, its extremity being lost in the space marked out by α *Lyræ*, β and γ *Draconis*, and δ *Cygni*. Its general aspect is represented in fig. 6. By 13^h its edge had reached *Polaris*, but moonlight then began to enfeeble it. About $11^h 45^m$ my wife called my attention to a faint ray of perfectly similar character, stretching under the square of *Ursa Major*, about $3°$ or $3\frac{1}{2}°$ broad, having ψ *Ursæ Majoris* in its lower edge, and *Cor Caroli* about $1°$ above its upper, and traceable about half way from the latter star to *Arcturus*. It pointed to the Comet, but in the twilight no connexion could be made out. About 20^m afterwards it had risen higher, so as to stand midway between ψ and γ *Ursæ Majoris;* its further part had now become much more distinct than before, perhaps more so than any other portion of the ray, and its termination was plainly visible near ϵ *Böotis;* some time afterwards I could not see it. From this circumstance, and the character of its motion, opposite to that of the mass of the tail, I concluded it could be only a cirrus cloud brought up by the north-west wind, though the peculiarity of its direction caused me, fortunately, to record it; and from this impression, and my having missed the corresponding beam in *Cassiopea* (which, according to Mr. Williams, was somewhat the brighter of the two), I imagined for some time that the perspective appearance of the tail on this night did not accord with its immediate proximity, as calculated by Mr. Hind; but as the western ray was plainly seen by Mr. Williams at Liverpool about $12^h 30^m$, passing midway between α and β *Ursæ Majoris*, and reaching down towards the head of the Comet, I think there can be little doubt that it was really a part of the tail, whose rapid motion of closing up towards the axis indicated that it was then in the act of leaving the immediate vicinity of the Earth; and thus this most interesting appulse, if not actual conjunction, appears to have been verified by positive observation. Mr. Williams also had supposed that his two rays might be only streaks of cloud, and had been induced, like myself, to record them from the peculiarity of their direction: happily the intervening distance between the observers was such as to remove any suspicion of the kind. That gentleman's sketch, I ought also to observe, gives so great a breadth and so scattered a character to the central portion of the train, that it becomes naturally connected

* A copy of the sketch accompanied Mr. Webb's paper.—Ed.

with these widely divergent lateral appendages. Under these circumstances it is not surprising that I should have failed in detecting any traces of a hollow structure, though I looked for them carefully. No anomalous ray could be perceived towards the Sun.

July 2. The tail was now slightly concave, instead of convex, towards the west; it could be traced nearly to *Wega*, or about 80°; neither of its edges was at all defined. In the comet eye-piece its central region at some distance behind the nucleus appeared slightly fainter than its sides. Its general direction to-night coincided nearly with the right (inverted) side of the innermost envelope in fig. 2.

July 4. Tail nearly straight; possibly a slight double curvature, first to the left (or west), then to the right, but it is quite uncertain. It appears more dense for some distance from the head; both sides are equally ill-defined. The nucleus seems to stand at the vertex of a wide but very ill-marked parabola, part of which is formed by the north edge of the fan, and within which was rather less light than at the sides; the coma, in passing off along each side of this space to form the train, was somewhat brighter on the north; but all this was so indistinct as to require close attention, and nothing like two separate streams could anywhere be seen, nor was there any anomalous ray.

July 5. The tail appears, as last night, a little denser at its origin on the north, or orbitally following side; and rapid cross-sweeping with the comet eye-piece detects a slightly darker interior, commencing near the nucleus, but not traceable for any considerable distance.

July 6. The tail is again slightly turned to the left.

July 8. Tail about 14° or 15°, and streaky to the naked eye. I am not sure whether I have not noticed this before. In the comet eyepiece it had a narrow ray in the centre, or rather, a little way behind the coma, I saw nothing but a faint ray, about 5′ broad by estimation, and several degrees in length. On the north side the coma passed off into a faint branch of about the same width, and perhaps 30′ long., fading gradually away; on the other side I could find nothing corresponding. Hence I concluded that this branch and the longer ray were the two sides of a hollow tail, till further examination, and especially with the finder, convinced me to the contrary. In this little instrument the whole tail rose in one stream from the whole coma; and the ray, having been previously perceived, could be seen to form its axis for some distance. Fig. 4 is the appearance in the comet eyepiece; fig. 9 that in the finder.

July 10. I studied the tail carefully, and think that I misconceived its structure the night before last: the two branches, as in fig. 4, are, after all, a double train with a darker interior. I was misled by its coming off from the coma with a sudden

turn downwards (inverted): the lower is the fainter and shorter of the two branches, reaching about 2°; the other is much the longer; it is broader than on the 8th, but, notwithstanding a very transparent sky, less defined. There is no other branch on the opposite side, and it is obviously the edge, and not the centre of the tail. Fig. 4 still suits it well: a very careful scrutiny with the finder detects no central ray. The bend downwards is very visible with this little glass, and perceptible to the naked eye.

July 15. Powers of 55 and 110 showed no dark interior, but it could be distinctly made out in the comet eyepiece, though not near the nucleus, and could be traced for about 1°. The streams on each side were nearly alike — possibly the orbitally preceding may be the more dense; the head still seemed, as it were, set on a little awry.

July 16 and 23. Hollow structure difficult to be perceived.

A few general remarks may be permitted at the close of these observations.

It may fairly be inferred, from the absence of any phasis, that the visible nucleus either contained no concentration of opaque matter, or shone by intrinsic light. Its axial rotation seems improbable, if, as may reasonably be supposed, the more luminous rays always issued from the same portions of it. On the other hand, some amount of libration might be deduced from the varying angles of position of certain portions of the sector, if only the measures could be thought worthy of sufficient confidence.

The similarity of the brilliant jet of June 30 to the streams which issued from the nucleus of Halley's Comet in 1835 is as obvious as that of the subsequently formed sector to some of the phenomena of the Comet of Donati; and the unsymmetrical arrangement, so evident in 1858, was again conspicuous. The sector was of later date than the envelopes, and much posterior to the perihelion passage. The descent of the envelopes upon the nucleus in the Comet's retreat from the sun corresponded with the similar process described by Herschel and Schröter in 1811; and this probably may have been the cause of the increasing apparent density of the whole coma.

There were no indications of rotation in the tail. Any general curvature which it may have possessed was masked by its position; but minor deviations in direction were sufficiently evident.

The obliquity of the sector and envelopes with respect to the axis of the tail might be thought to indicate that a stronger repulsion or a less resisted emissive force acted in one direction from the nucleus than in the opposite. The nebulous veils, without any difference as to extent, showed invariably greater distinctness and definedness on one side of the head than on the other. Unfortunately the position of the Comet's orbit

was such during these observations that it was not possible to obtain a fair view of the arrangement in the plane of its motion, or to form a satisfactory idea how far these phenomena may have arisen from any external resistance.

Hardwick Parsonage, December 24th, 1861.

Comet I., 1862.

The Comet appears to have been first observed by Mr. Schmidt, at Athens, about half-past ten on the evening of July 2, near the stars β, ϱ, σ, *Cassiopeiæ*. It was seen about midnight by M. Tempel, at Marseilles, and by Mr. Bond, at Harvard College, on the evening of July 3d (see *Ast. Nach.* Nos. 1369, 1370, and 1374). Elements have been computed by Dr. Seeling, Mr. Hall, Mr. H. P. Tuttle, and Dr. Weiss; those of Dr. Weiss, computed from the Athens and Marseilles Observations of July 2, 3, 5, are as follows:—

$$
\begin{array}{lll}
T & = \text{June } 22{\cdot}5430 \text{ G.M.T.} & \\
\Omega & = 324^\circ\ 30'{\cdot}4 & \multirow{2}{*}{\}\ \text{Mean Eq. } 1862{\cdot}0.} \\
\pi & = 298\ \ 35{\cdot}2 & \\
\iota & = \ \ \ 8\ \ 14{\cdot}2 & \\
\log q & = 9{\cdot}99242. &
\end{array}
$$

Motion retrograde.

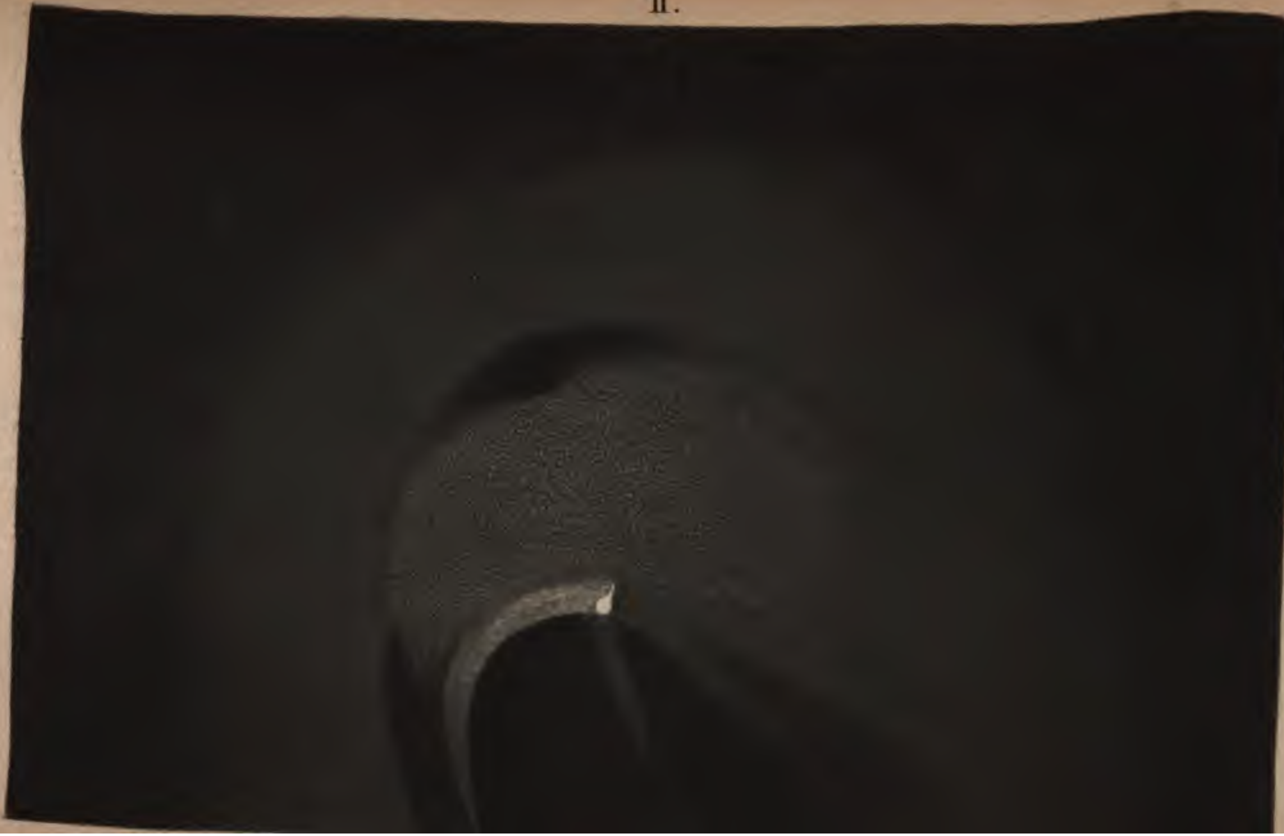
Comet II., 1862.

The Comet was discovered by MM. Pacinotho and Toussaint, at Florence, on the 22d July (*Ast. Nach.* No. 1374). The elements, as calculated by Dr. Hornstein, from observations of July 24, 27, and August 1, are as follows:—

$$
\begin{array}{lll}
T & = 1862, \text{ Aug. } 23{\cdot}71395, \text{ Berlin M.T.} & \\
\Omega & = 137^\circ\ 4'\ 32''{\cdot}8 & \text{Mean Eq.} \\
\pi & = 344\ \ 16\ \ 13{\cdot}6 & 1862{\cdot}0. \\
\iota & = \ \ 66\ \ \ 3\ \ \ 4{\cdot}1 & \\
\log q & = 9{\cdot}9847732. &
\end{array}
$$

Motion retrograde.

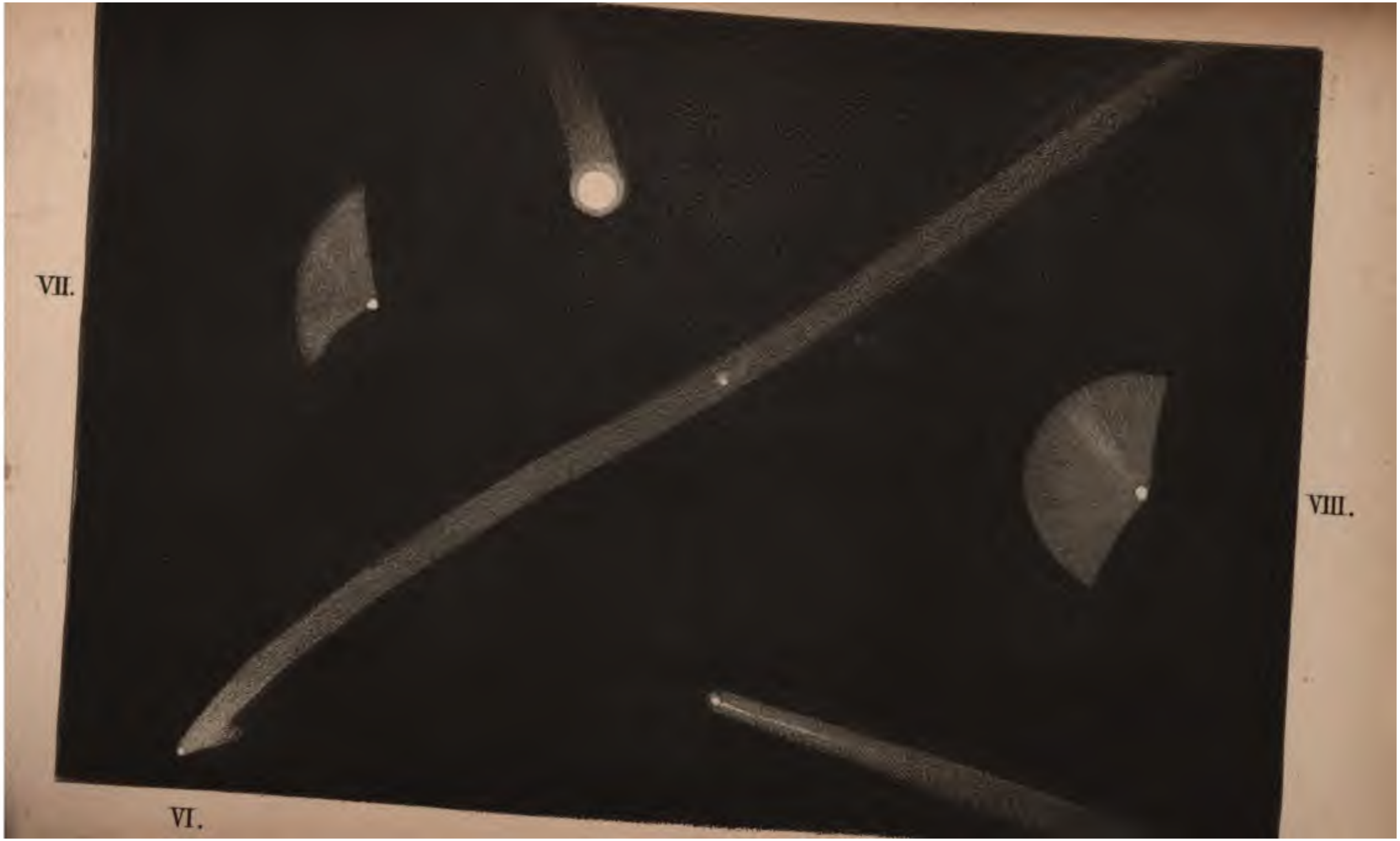
II.



July 8 1861.

July 4, 1861.

Malby & Sons, Lith.


VII.
VIII.
VI.

Communications in reference to this Comet have been received from C. B. Chalmers, Esq., and Lieutenant Chimmo. Mr. Chalmers (Shanty Bay, County of Simcoe, Canada West), with his 5-foot equatoreally-mounted telescope by G. Dollond, saw the Comet, August 11, about 10 P.M., in the constellation *Camelopardus;* approximate Declination $+80^\circ 51'$, Comet moving north at the rate of about $50'$ in twenty-four hours; there was no tail, but a rather extensive coma; the nucleus bore a faint illumination of the wires.

Lieut. Chimmo (Canna Island, Hebrides, lat 57° N., long. $6^\circ 30'$ W.) observed the Comet on the night of Sept. 1, about $9^h 51^m$ G.M.T. He observed the distances of the Comet from

	°	′	″
Ursa Major α	67	5	30
Ditto η	39	58	30
Arcturus	73	39	30
α Lyræ	41	22	30

from which the position is laid down on a drawing which accompanied his letter. The altitude was $25^\circ 48' 30''$.

The Moon had just set, and the Comet's position was made under the disadvantage of a bright Aurora, which was coruscating towards the zenith, from an arch of about 14° elevation, from N.N.W. to N.N.E. (mag.)

The tail of the Comet was inclined to the E.S.E. (mag.), and measured (with unassisted vision) half a degree nearly, or about equal to fifty millions of miles.

The nucleus was well defined, and equal to a star of the third or fourth magnitude, surrounded by considerable nebulosity of an irregular oval, perhaps paraboloidal. The jet apparently waved to and fro: this is however doubtful, and it may be an illusion, caused probably by the shooting coruscations of the Aurora.

The most attractive feature of the Comet was the well-defined limb of the south or underneath portion of the tail.

The instruments used were a common 3-foot telescope of 1·6 field, and a sextant, being all that the observer had; but there was the assistance of a pure and transparent atmosphere.

Hansen's Tables de la Lune.

A list, containing all the Errata discovered in the above Tables at the *Nautical Almanac* Office, and otherwise known at the Royal Observatory up to the date of March 10, 1862, has lately been issued in the form of a *Nautical Almanac*

Circular, and distributed from the Royal Observatory. All possessors of the Tables who have not received a copy of this list may obtain it on application to the Royal Observatory, Greenwich, or to the sources from whence they received the Tables.

Death of Capt. Jacob.

The Council have great sorrow in notifying to the Fellows of the Society the decease of Capt. Jacob, within a few days after his arrival in India, and that the important expedition on which he had set out is thereby brought to a most unexpected and unfortunate close. As the next Annual Report will contain fuller particulars of his life and labours, and in particular of this the closing event, the Council now confine themselves to stating that Capt. Jacob sailed from England in the Hertfordshire, by way of the Cape, on the 20th of April last; and after enjoying good health on the voyage, landed at Bombay on the 8th of August, with a slight cold, which appears from the accounts received to have been increased during the exertions of superintending the landing of his family and instruments. He proceeded, however, within two or three days to his destination, Poonah, where medical aid was called in, in consequence of an abscess in the throat and an attack of inflammation of the liver which had supervened. Leeches were very freely applied; and it is fruitless now to remark further than that, on the 16th, this admirable observer and excellent man was no more.

Another severe loss has been incurred by the decease of an Associate of the Society, the veteran Astronomer Carlini, who died in his 77th year, after a short but painful illness, on the 29th of August, 1862. An account of his life and scientific labours (carried on with unbroken activity for nearly sixty years) will be given in the ensuing Annual Report.

Mr. Dawes calls attention to some typographical errors in his paper, "Saturnian Phenomena," as printed in the last number of the *Monthly Notices*, viz., page 297, line 16 from the bottom, the word "*side*" should be in Roman letters, and page 298, line 7, the word "ring" should be in Italics; and line 38, the word "damp" should be "dense," the conjecture referred to being ***the existence of a pretty dense atmosphere on the rings.***

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Printed by Strangeways and Walden, Castle St. Leicester Sq., and Published at the Apartments of the Society, Nov. 10, 1862.

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